Greater Sage-Grouse Interim Status Update

U.S. Fish and Wildlife Service
Mountain-Prairie Region
Wyoming Ecological Services Office[1]

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PURPOSE

The purpose of this document is to provide an update on our synthesis of biological information relative to the status of the greater sage-grouse, and the threats to the species that may affect its viability and persistence. It is interim because information and analyses contained in this update are incomplete. This update does not include policy considerations or a determination of whether the greater sage-grouse is warranted for listing under the Endangered Species Act (ESA), and the information included here should not be used to infer such a determination. This document is an interim step in completing our greater sage-grouse status review, and will inform our eventual finding on whether the greater sage-grouse should be listed under the ESA.

EXECUTIVE SUMMARY

Since we last reviewed the status of the greater sage-grouse in 2005, extensive new information has been accumulated. This new information includes a large volume of new scientific research, a large number of on-the-ground conservation actions, and a number of actions that negatively affect the species and its habitat. This Interim Status Update focuses primarily on characterizing the species' biology and ecology, and begins to enumerate, in a systematic and scientific manner, the vulnerabilities of the species and the specific threats to the species related to those vulnerabilities. Due to our incomplete review and analyses of new information at this time, this update focuses little on how threats may affect the species' persistence and viability. The presentation of data and associated summaries and analyses in this update reflect a step in a longer process to complete a comprehensive review of the greater sage-grouse.

The information presented here portrays a species that remains vulnerable to various activities on the landscape. The amount and scale of oil and gas exploration and development has expanded since 2005, as has loss of habitat due to increased fire frequency which has exacerbated the spread of invasive species such as cheatgrass. These concerns were identified as primary threats in our 2005 finding and remain so, but with more intensity and on a larger scale. Additional concerns include an increase in the use of sagebrush habitat for renewable energy such as wind power, and the increased threat posed by West Nile Virus. Concomitantly with this increase in threats, there has

been a dearth of effective State or Federal measures adopted to assist in avoiding, minimizing or mitigating the known significant impacts to greater sage-grouse.

Despite a dramatic decline in sage-grouse numbers in the last 40 years, trends in recent years reflect variability in this decline, and some populations have stabilized or possibly increased. Although estimates of population size are difficult to obtain with accuracy and precision, there still appear to be hundreds of thousands of sage-grouse extant across its range. Nonetheless, the distribution of these numbers is not uniform across the range of the species. Approximately 50 percent of these birds occur in a relatively small portion of the species range (within 1 of 7 floristic regions or State wildlife agency "Management Zones"), and 90 percent occur within 3 Management Zones, with the greatest intensity of threats generally concentrated in these areas. Our ongoing and subsequent analyses of threats in these Management Zones will allow us to accurately characterize the current status of greater sage-grouse.

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CONSERVATION STATUS

Within the United States, greater sage-grouse are under the management of State wildlife agencies across its entire range. All 11 have final conservation or management plans for the species. These plans are in various stages of implementation, and generally contain information to help guide the development and execution of more focused conservation efforts and planning at a local level. Currently nine of the States still permit harvest. The States manage approximately 5 percent of sage-grouse habitat. There are no special provisions for land management relevant to sage-grouse on private lands, which comprise approximately 31 percent of sage-grouse habitat.

The Bureau of Land Management (BLM) manages approximately 51 percent of the extant sage-grouse range (Knick 2008, p. 30). The BLM has designated the greater sage-grouse a sensitive species across all 11 States in the sage-grouse range. As defined by BLM Manual 6840 – Special Status Species Management (BLM 2001) “The protection provided by the policy for candidate species shall be used as the minimum level of protection for BLM sensitive species” (BLM 2001). The BLM policy regarding candidate species includes: implementation of management plans for conserving the species and its habitats; ensuring actions authorized, funded, or carried out by the BLM do not contribute to the need for the species to become listed; ensuring the species are considered in land use plans; developing and/or participating in management plans and species and habitat assessments; and monitoring the species for evaluating of management objectives (BLM 2001). BLM's Manual 6840 is currently under revision and we have no information as to how sage-grouse will be considered under the new manual.

The U.S. Forest Service (USFS) manages approximately 8 percent of sage-grouse habitats (Knick 2008, p. 30). Sage-grouse are managed under individual National Forest land and resource management plans which direct Forests to manage habitat to maintain viable populations of existing native vertebrate species on National Forest System lands (1982 rule, 36 CFR 219.19). Some Forests have designated sage-grouse as management indicator species, and were selected because their population changes are believed to reflect the effects of management activities (1982 rule, 36 CFR 219.19(a)). The regulation requires that during the planning process, each alternative considered needed to establish objectives for the maintenance and improvement of habitat for management indicator species, to the degree consistent with overall multiple use objectives of the alternative.

The remaining 5 percent of sage-grouse habitats in the United States are managed by a variety of Federal agencies, including the U.S. Fish and Wildlife Service, Bureau of Indian Affairs, Department of Energy, and Bureau of Reclamation. Sage-grouse have no special management status with those agencies.

Greater sage-grouse are cooperatively managed by Provincial and Federal governments in Canada. The species is afforded Federal legal protection under schedule 1 of the Species at Risk Act (SARA; Canada Gazette, Part III, Chapter 29, Vol. 25, No. 3, 2002).

BIOLOGY AND ECOLOGY OF GREATER SAGE-GROUSE

Species Description

The greater sage-grouse (*Centrocercus urophasianus*) is the largest North American grouse species. Adult male greater sage-grouse range in length from 66 to 76 centimeters (cm) (26 to 30 inches (in)) and weigh between 2 and 3 kilograms (kg) (4 and 7 pounds (lb)). Adult females are smaller, ranging in length from 48 to 58 cm (19 to 23 in) and weighing between 1 and 2 kg (2 and 4 lb). Males and females have dark grayish-brown body plumage with many small gray and white speckles, fleshy yellow combs over the eyes, long pointed tails, and dark green toes. Males also have blackish chin and throat feathers, conspicuous phylloplumes (specialized erectile feathers) at the back of the head and neck, and white feathers forming a ruff around the neck and upper belly. During breeding displays, males exhibit olive-green apteria (fleshy bare patches of skin) on their breasts (Schroeder et al. 1999, p.2).

Taxonomy

Greater sage-grouse are a members of the Phasianidae family, it is one of two congeneric species; the other species in the genus is the Gunnison sage-grouse (*C. minimus*). Until recently, the species was described as including sage-grouse in south-central Colorado and eastern Utah. In 2000, sage-grouse from extant populations in southwestern Colorado and southeastern Utah were classified as a separate species (Young et al. 2000, pp. 447-451). Therefore, Gunnison sage-grouse were removed from the candidate list on April 18, 2006 (71 FR 19954). Gunnison sage-grouse are not further discussed in this update.

Uncertainty about subspecies validity: In 1957, the American Ornithological Union (AOU) recognized two subspecies of the greater sage-grouse, the eastern (*C. u. urophasianus*) and western (*C. u. phaios*), based on information from Aldrich (1946, p 129). The subspecies designation was based on difference in coloration (specifically reduced white markings and darker feathering on western birds) in 11 museum specimens. The AOU has not published a revised edition of the Check-list of North American Birds at the subspecies level since 1957, thus AOU has not reconsidered the taxonomy of the subspecies in light of scientific information that has become available since then (Dr. Banks, Bird Section, Biological Survey Unit, National Museum of Natural History, pers. comm. 2000).

There has been disagreement as to the validity of the subspecies designations for greater sage-grouse (Braun 1992 and Aldrich 1992, both in Drut 1994; Banks 1992, 2000, 2002) with recognition that these designations may be inappropriate (Johnsgard 1983, p. 109;

Schroeder et al. 1999; IUCN 2000, p. 62; Johnsgard 2002, p. 108; Benedict et al. 2003, p. 301). Benedict et al. (2001) concluded that "...additional morphological, behavioral, and genetic studies are warranted to further investigate this potential taxonomic error", indicating substantial scientific uncertainty on this point.

Geography: The delineation between eastern and western subspecies is only vaguely defined and has changed from its original description over time (Aldrich 1946, p. 129; Aldrich and Duvall 1955 p. 12, AOU 1957, p. 139, Aldrich 1963, pp. 539-541). The boundary between the subspecies is generally described along a line starting on the Oregon-Nevada border south of Hart Mountain National Wildlife Refuge and ending near Nyssa, Oregon (Aldrich and Duvall 1955, p. 12; Aldrich 1963, pp. 539-541). Aldrich described the original eastern and western ranges in 1946 (Aldrich 1946, p. 129), while Aldrich and Duvall (1955, p. 12) and Aldrich (1963, pp. 539-541) also described an intermediate form in northern California, presumably in a zone of intergradation between the subspecies. All of Aldrich's citations include a portion of Idaho within the western subspecies' range, but the 1957 A.O.U. designation included Idaho as part of the eastern subspecies (A.O.U. 1957, p. 139).

Morphology and Behavior: Banks (1992) found that while differences between the eastern and western subspecies specimens are discernible, individual morphological variation in greater sage-grouse, such as plumage coloration, is extensive. Further, given current taxonomic concepts, he doubted that most current taxonomists would identify a subspecies based on minor color variations from a limited number of specimens, as were available to Aldrich during the mid-1900s (Aldrich 1946 and 1963).

Schroeder (2008) has examined previously collected morphological and behavioral data from both published and unpublished sources. Analyses of the available morphometric data found statistically significant differences in numerous characteristics including body mass, wing length, tail length, and primary length. Many of these differences were associated with sex and age, but body mass also varied by season. There were also substantial morphometric differences among populations. Despite finding variations within these characteristics however, Schroeder did not find morphometric differences between populations within the “western subspecies” range and those outside that area that would be consistent with genetic isolation (Schroeder 2008, p.10). The only data available with respect to behavior are for strutting behavior on leks, a key component of mate selection. An examination of these data also did not show differences that support a subspecies designation (Schroeder 2008, p. 9).

Genetics: Genetic research can sometimes augment or refine taxonomic definitions which are based on morphology and/or behavior (discussed in Hait et al. 2006, p. 1586; Oyler-McCance and Quinn 2008, p. 19, among others). Several studies investigating the rangewide genetic profiles of greater sage-grouse have been undertaken (e.g. Quinn et al. 1997; Benedict and Quinn 1998; Benedict et al. 2003; Oyler-McCance et al. 2005).

To investigate taxonomic questions and examine levels of gene flow and connectedness among populations, Oyler-McCance et al. (2005) greatly extended the sampling range and density of previous studies and provided a comprehensive examination of the distribution of genetic variation across the entire range of Greater Sage-grouse, using both mitochondrial and nuclear DNA sequence data. Oyler-McCance et al. (2005) found that the overall distribution of genetic variation showed a gradual shift across the range in both mitochondrial and nuclear data sets. This can be viewed as the possible existence of multiple discrete populations among which dispersal and gene flow are restricted (Campton 2007, p. 4), and is more consistent with an isolation-by-distance relationship than that of two subspecies. In general, the greater sage-grouse populations follow an isolation-by-distance model of restricted gene flow (Oyler-McCance et al. 2005, p. 1293).

Oyler-McCance and Quinn (2008) reviewed available studies that used molecular genetic approaches, including Oyler-McCance et al. (2005). They examined the genetic data bearing on the delineation of the western and eastern subspecies of greater sage-grouse, and determined that the distinction is not supported by the genetic data.

Habitat and Life History Characteristics

Greater sage-grouse depend on a variety of shrub-steppe habitats throughout their life cycle, and are considered obligate users of several species of sagebrush (e.g., Wyoming big sagebrush (*Artemisia tridentata var. wyomingensis*), mountain big sagebrush (*A. t. vaseyana*), and basin big sagebrush (*A. t. tridentata*) (Patterson 1952, p. 48; Braun et al. 1976, p. 168; Connelly et al. 2000a, pp. 970-972; Connelly et al. 2004, p. 4-1). Greater sage-grouse also use other sagebrush species such as low sagebrush (*A. arbuscula*), black sagebrush (*A. nova*), fringed sagebrush (*A. frigida*) and silver sagebrush (*A. cana*) (Schroeder et al. 1999, pp. 4-5; Connelly et al. 2004, p. 3-4). Thus, sage-grouse distribution is strongly correlated with the distribution of sagebrush habitats (Schroeder et al. 2004, p. 364). Sage-grouse exhibit strong site fidelity (loyalty to a particular area) to breeding and nesting (Connelly et al. 2004, p. 3-1).

During the spring breeding season, male sage-grouse gather together to perform courtship displays on areas called leks. Areas of bare soil, short-grass steppe, windswept ridges, exposed knolls, or other relatively open sites typically serve as leks (Patterson 1952, p. 83; Connelly et al. 2004, p. 3-7 and references therein). Leks are often surrounded by denser shrub-steppe cover, which is used for escape, thermal and feeding cover. Leks can be formed opportunistically at any appropriate site within or adjacent to nesting habitat (Connelly et al. 2000a, p. 970), and therefore lek habitat availability is not considered to be a limiting factor for sage-grouse (Schroeder 1999, p. 4). Leks range in size from less than 0.04 hectare (ha) (0.1 acre (ac)) to over 36 ha (90 ac) (Connelly et al. 2004, p. 4-3) and can host from several to hundreds of males (Johnsgard 2002, p. 112). Males defend individual territories within leks and perform elaborate displays with their specialized plumage and vocalizations to attract females for mating. A relatively small number of dominant males accounts for the majority of breeding on each lek (Schroeder et al. 1999, p. 8). Males do not participate in incubation of eggs or rearing chicks.

Females have been documented to travel more than 20 km (12.5 mi) to their nest site after mating (Connelly et al. 2000a, p. 970), but distances between a nest site and the lek on which breeding occurred is variable (Connelly et al. 2004, p. 4-5). Average distance between a female's nest and the lek on which she was first observed ranged from 3.4 km (2.1 miles) to 7.8 km (4.8 miles) in studies examining 301 nest locations (Schroeder et al., 1999 p. 12). Research by Bradbury et al. (1989, p. 22) and Wakkinen et al. (1992, p. 382) demonstrated that nest sites are selected independent of lek locations.

Productive nesting areas are typically characterized by sagebrush with an understory of native grasses and forbs, with horizontal and vertical structural diversity that provides an insect prey base, herbaceous forage for pre-laying and nesting hens, and cover for the hen while she is incubating (Gregg 1991, p. 19; Schroeder et al. 1999, p. 4; Connelly et al. 2000a p. 971; Connelly et al. 2004, pp.4-17,18). Sage-grouse may also use other shrub or bunchgrass species for nest sites (Klebenow 1969, p. 649; Connelly et al. 2000a, p.970; Connelly et al. 2004, p. 4-4). Shrub canopy and grass cover provide concealment for sage-grouse nests and young, and are critical for reproductive success (Barnett and Crawford 1994, p.116; Gregg et al. 1994, p.164; DeLong et al.1995, p. 90; Connelly et al. 2004, p. 4-4). Published vegetation characteristics of successful nest sites included a sagebrush canopy cover of 15-25 percent, sagebrush heights of 30 – 80 cm, and grass/forb cover of 18cm (Connelly et al. 2000a, p. 977).

Sage-grouse clutch size ranges from 6 to 13 eggs (Schroeder et al. 2000). Nest success (one or more eggs hatching from a nest), as reported in the scientific literature, ranges from 15 to 86 percent of initiated nests (Schroeder et al. 1999, p. 11), and is typically lower than other prairie grouse species (Connelly et al. 2000a, p. 970). This indicates a lower intrinsic (potential) population growth for greater sage-grouse than for most game bird species (Schroeder et al. 1999, p. 13-14). Re-nesting only occurs if the original nest is lost (Schroeder et al. 1999, p. 11). Re-nesting rates average 28.9 percent (based on 9 different studies) with a range from 5 to 41 percent (Connelly et al. 2004. p. 3-11). The impact of re-nesting on annual productivity for most populations is unclear and thought to be limited (Crawford et al. 2004, p. 4). In north-central Washington State, re-nesting contributed to 38 percent of the annual productivity of that population (Schroeder 1997, p. 937). However, the author in this study postulated that the re-nesting efforts in this population may be greater than anywhere else in the species' range because environmental conditions allow a longer period of time to success fully rear a clutch (Schroeder 1997, p. 939).

Hens rear their broods in the vicinity of the nest site for the first 2 to 3 weeks following hatching (0.2 to 5 km (0.1 to 3.1 miles), based on two studies in Wyoming; Connelly et al. 2004, p. 4-8). Forbs and insects are essential nutritional components for chicks (Klebenow and Gray 1968, p. 81; Johnson and Boyce 1991, p. 90; Connelly et al. 2004, p. 4-9). Therefore, early brood-rearing habitat must provide adequate cover (sagebrush canopy cover of 10 to 25 percent; Connelly et al. 2000a, p. 977) adjacent to areas rich in forbs and insects to assure chick survival during this period (Connelly et al. 2004, p. 4-9).

All sage-grouse gradually move from sagebrush uplands to more mesic areas during the late brood-rearing period (3 weeks post-hatch) in response to summer desiccation of herbaceous vegetation (Connelly et al. 2000a, p. 971). Summer use areas can include sagebrush habitats as well as riparian areas, wet meadows and alfalfa fields (Schroeder et al. 1999, p. 4). These areas provide an abundance of forbs and insects for both hens and chicks (Schroeder et al. 1999, p. 4; Connelly et al. 2000a, p. 971). Sage-grouse will use free water although they do not require it since they obtain their water needs from the food they eat. However, natural water bodies and reservoirs can provide mesic areas for succulent forb and insect production, thereby attracting sage-grouse hens with broods (Connelly et al. 2004, p. 4-12). Broodless hens and cocks will also use more mesic areas in close proximity to sagebrush cover during the late summer, often arriving before hens with broods (Connelly et al. 2004, p. 4-10).

As vegetation continues to desiccate through the late summer and fall, sage-grouse shift their diet entirely to sagebrush (Schroeder et al. 1999, p. 5). Sage-grouse depend entirely on sagebrush throughout the winter for both food and cover. Sagebrush stand selection is influenced by snow depth (Patterson 1952, p. 184; Hupp and Braun 1989, p. 827), availability of sagebrush above the snow to provide cover (Connelly et al. 2004, p. 4-13, and references therein) and, in some areas, topography (e.g. elevation, slope and aspect; Beck 1977, p. 22; Crawford et al. 2004, p. 5).

Many populations of sage-grouse migrate between seasonal ranges in response to habitat distribution (Connelly et al. 2004, p. 3-5). Migration can occur between winter and breeding/summer areas, between breeding, summer and winter areas, or not at all. Migration distances of up to 161 kilometers (km) (100 mi) have been recorded (Patterson 1952, p. 189); however, distances vary depending on the locations of seasonal habitats (Schroeder et al. 1999, p. 3). Migration distances for female sage-grouse generally are less than for males (Connelly et al. 2004, p. 3-4), but in one study in Colorado, females travelled further than males (Braun and Beck, 1976). Almost no information is available regarding the distribution and characteristics of migration corridors for sage-grouse (Connelly et al. 2004, p. 4-19). Sage-grouse dispersal (permanent moves to other areas) is poorly understood (Connelly et al. 2004, p. 3-5) and appears to be sporadic (Dunn and Braun 1986, p. 89). While sage-grouse are dependent on large, interconnected expanses of sagebrush (Patterson 1952; Connelly et al. 2004, pp. 4-15), information is not available regarding minimum sagebrush patch sizes required to support populations of sage-grouse.

Sage-grouse typically live between 1 and 4 years, but individuals up to 10 years of age have been recorded in the wild (Schroeder et al. 1999). Hens typically survive longer due to a disproportionate impact of predation on leks to males (Schroeder et al. 1999, p. 14). Juvenile survival (from hatch to first breeding season) is affected by food availability, habitat quality, harvest, and weather. Based on a review of many field studies, documented juvenile survival rates range from 7 to 60 percent (Crawford et al. 2004). High mortality rates in juveniles may be associated with habitat quality, with rates increasing in poor habitats (Schroeder et al. 1999, p. 14). The average annual survival rate for male sage-grouse (all ages combined) documented in various studies ranged from 38 to 60 and 55 to 75 percent for females (Schroeder et al. 1999, p. 14). Higher female survival rates account for a female-biased sex ratio in adult birds (Schroeder 1999, p. 14; Johnsgard 2002, p. 621). Although seasonal patterns of mortality have not been thoroughly examined, over-winter mortality appears to be low (Connelly et al. 2000b, p. 229; Connelly et al. 2004, p. 9-4). While both males and females are capable of breeding the first spring after hatch, young males are rarely successful due to the dominance of older males on the lek (Schroeder et al. 1999, p. 14).

Range and Distribution

Prior to settlement of the western North America by European immigrants in the 19th century, greater sage-grouse occurred in 13 States and 3 Canadian provinces—Washington, Oregon, California, Nevada, Idaho, Montana, Wyoming, Colorado, Utah, South Dakota, North Dakota, Nebraska, Arizona, British Columbia, Alberta, and Saskatchewan (Schroeder et al. 1999, p. 2; Young et al. 2000, pp. 445; Schroeder et al. 2004, p. 369). Sagebrush habitats that potentially supported sage-grouse occurred over approximately 1,200,483 km^2 (463,509 mi^2) before 1800 (Schroeder et al. 2004, p. 366). Currently, greater sage-grouse occur in 11 States and 2 Canadian provinces, ranging from extreme southeastern Alberta and southwestern Saskatchewan, south to western Colorado, and west to eastern California, Oregon, and Washington (Miller et al., in press; Figure 1).

Figure 1: Current and pre-settlement range of the greater sage-grouse (from Schroeder et al. 2004).

Sage-grouse have been extirpated from Nebraska, British Columbia, and possibly Arizona (Schroeder et al. 1999, p. 2; Young et al. 2000 p. 445; Schroeder et al. 2004, p. 369). Current distribution of the greater sage-grouse is estimated at 668,412 km^2 (258,075 mi^2) or 56 percent of the potential pre-settlement distribution (Schroeder et al. 2004, p. 369; Connelly et al. 2004, p. 6-9).

Population Size

Following review of published literature and anecdotal reports, Connelly et al. (2004, ES-1-3) concluded that the abundance and distribution of sage-grouse have declined from pre-settlement numbers. Most of the historic population changes were the result of local extirpations, which has been inferred from a 44 percent reduction in sage-grouse distribution described by Schroeder et al. 2004 (Connelly et al. 2004, p. 6-9).

Estimates of greater sage-grouse abundance were mostly anecdotal prior to the implementation of systematic surveys in the 1950's (Braun 1998). Early reports suggested the birds were abundant throughout their range. However, concerns about extinction were raised in early literature primarily due to market hunting and habitat alteration (Hornaday 1916). Some authors suggest that greater sage-grouse populations have been declining for at least 30 years (Braun 1995, Connelly and Braun 1997, Aldridge and Brigham 2003, Schroeder et al. 2004). Various abundance estimates (i.e., estimates of the number of birds rangewide) have been made. For the most part the estimates have been based on lek counts and/or harvest data.

Use of lek counts to estimate abundance: Problems regarding inconsistent sampling protocols for lek surveys (e.g. number of times a lek is counted, observer bias) were identified by Stiver et al. (2006), and many of those problems still persist. Additionally, lek data are biased due to the method of collection (e.g. observer bias/experience, time of day counted, time in season counted) and the unknown relationship of lek counts to population size (WAFWA 2008, p. 3), precluding the use of these data in the development of an accurate population estimate. However, the annual counting of males on leks remains the primary approach to monitor long-term trends of populations (WAFWA 2008, p. 3). Given the limitations of lek data to formulate statistical population estimates, the states rely on actual counts of birds on leks and harvest data to estimate population size. However, we are unable to provide an estimate of the current rangewide population of sage-grouse using this approach because only two states provided us lek count data within the last 2 years.

Use of harvest data to estimate abundance: Other sources of population data, including harvest data are even more dated (Table 1). State wildlife agencies manage hunting with a harvest goal of no more than 5 to 10 percent of the fall population of birds (see discussion on hunting below), and the agencies use annual harvest numbers to estimate population size. Statistically the use of harvest data is of limited value however, since both harvest and population size on which harvest is based are estimates. Therefore, population numbers generated from harvest data can only be considered rough estimates.

Table 1: Population estimates from State sage-grouse conservation plans, lek counts and harvest information.

Location	Data year	Source	Estimated population
CA/NV	2004	CA/NV Conservation Assessment (2004, pg. 26)	88,000
CO	2007	2007 CO Conservation plan, with male lek count adjusted by a 1.6 multiplier (sex ratio females:males)	22,646
ID	2007	Calculated based on the assumption of 5 percent	98,700

		of the population is harvested	
MT	2007	Calculated based on the assumption of 5 percent of the population is harvested	62,320
ND	2007	NDGF web page (last updated in 2007)	1,500
OR	2003	2003 Oregon conservation plan estimate (Hagen 2005, pg. 27)	40,000
SD	2008	Lek counts adjusted (assumed 75 percent males seen, and a 2:1 female to male ratio (Robinson 2008)	308
UT	2002	2001 UDOT management plan (2002, pg. 13)	12,999
WA	2003	WDFW Conservation Plan (2004, p. 21)	1,059
WY	2007	Calculated based on the assumption of 5 percent of the population is harvested	207,560
Canada	2008	Environment Canada web page	1,000

Estimates of abundance: Braun (1998) estimated that the minimum 1998 rangewide spring population numbered about 157,000 sage-grouse, derived from numbers of males counted on leks. The same year state wildlife agencies within the range of the bird estimated the population was at least 515,000 based on lek counts and harvest data (C. Warren, U.S. Fish and Wildlife Service, pers. comm. Sept. 15, 2008). The Service estimated the rangewide abundance of sage-grouse in 2000 was between a minimum of 100,000 (taken from Braun (1998)) up to 500,000 birds (based on harvest data from Idaho, Montana, Oregon and Wyoming, with the assumption that 10 percent of the population is typically harvested) (65 FR 51578). In 2003, based on increased lek survey efforts, Connelly et al. (2004, p. 13-5) concluded that rangewide population numbers were likely much greater than the 157,000 estimated by Braun in 1998, but they were unable to generate a rangewide population estimate.

Estimates of rangewide abundance can be calculated using estimates of population trends. Connelly et al. (2004) reports a 0.37 percent rate of decline from 1986 through 2003, and WAFWA (2008) reports a 1.4 percent decline from 1986 and 2007, respectively (see population trends below). Applying these rates to the State population estimates in Table 1 results in rangewide estimates of population size of 532,304 birds and 521,865 birds, respectively. Alternatively, the most recent rangewide estimate from the states in 1998 was 515,000. Applying these same rates of decline to this estimate produces a rangewide estimate of population size of 496,259 and 447, 277 using Connelly et al (2004) and WAFWA (2008) respectively. While these estimates rely on many untested assumptions, they do reflect a likely rangewide current population of more than Braun's (1998) minimum estimate of 157,000 birds.

Population trends

Periods of historical decline in sage-grouse abundance occurred from the late 1800s to the early-1900s (Hornaday 1916, pp. 179-221; Crawford 1982, pp 3-6; Drut 1994, pp 2-5; Washington Department of Fish and Wildlife 1995; Braun 1998; Schroeder et al. 1999, p. 1). Other declines in sage-grouse populations occurred in the 1920s and 1930s, and then again in the 1960s and 1970s (Connelly and Braun 1997, pp. 3-4; Braun 1998). Declines in the 1920s and 1930s were attributed to hunting, and declines in the 1960s and 1970s were primarily as a result of loss of habitat quality and quantity (Connelly and Braun 1997, p. 2). State wildlife agencies were sufficiently concerned with the decline in the 1920s and 1930s that many closed their hunting seasons and others significantly reduced bag limits and season lengths as a precautionary measure (Patterson 1952, pp. 30-33; Autenrieth 1981, p.10).

Using lek counts as an index for abundance, Connelly et al. (2004, p. 6-28) reported rangewide declines from 1965 through 2003. Declines averaged 2 percent per year from 1965 to 2003. Dividing this time period into two segments shows how the rate of decline has changed over time. The decline was more dramatic from 1965 through 1985, with an average annual change of 3.5 percent. Sage-grouse population numbers in the late 1960s and early 1970s were likely two to three times greater than current numbers (Connelly et al. 2004, p. 6-71). However, the rate of decline rangewide slowed to 0.37 percent annually during 1986 to 2003, and some populations increased (Connelly et al. 2004, p. 6-71).

In 2008, the Western Association of Fish and Wildlife Agencies (WAFWA) conducted new population trend analyses that incorporated an additional 4 years of data beyond the Connelly et al. 2004 analysis. Although the WAFWA analyses used different statistical techniques, lek counts were also the basis for the analyses. WAFWA results were similar to Connelly et al. (2004) in that a long-term population decline was detected during 1965 to 2007, i.e., the average annual change was 3.1 percent (WAFWA 2008, p. 12). WAFWA attributed the decline to the reduction in number of active leks (WAFWA 2008, p. 51). Similar to Connelly et al. (2004), the WAFWA analyses determined that the decline lessened during 1985 to 2007 (average annual change of 1.4 percent annually) (WAFWA 2008, p 58).

Population trends by state were also similar between Connelly et al. (2004) and WAFWA (2008) although there were minor differences (Table 2). WAFWA attributed these differences to continuing declines in most areas, differences in input data due to attempts to minimize error, and differences in analytical techniques (WAFWA 2008, p. 51). However, both analyses documented a long-term decline of greater sage-grouse from 1965 to the most recent year included in each study (2003 for Connelly et al., and 2007 for WAFWA), with a non-significant rangewide decline from 1986 to the most recent year included in the study (2003 or 2007).

Table 2: Comparison of the average annual rates of change in greater sage-grouse lek counts between Connelly et al. 2004 and WAFWA 2008.

State	Avg. rate of change Connelly et al. (2004) 1965 - 2003	Avg. rate of change WAFWA (2008) 1965 - 2007
California	+ 0.7 percent	- 1.0 percent
Colorado	+ 1.0 percent	+ 2.2 percent
Idaho	- 1.5 percent	- 4.4 percent
Montana	- 1.6 percent	- 3.2 percent
Nevada	- 2.1 percent*	- 2.0 percent
North Dakota	- 2.8 percent	- 3.8 percent
Oregon	- 3.5 percent	- 3.7 percent
South Dakota	No estimate**	+ 0.8 percent
Utah	- 0.35 percent	- 2.9 percent
Washington	- 4.8 percent	- 5.1 percent
Wyoming	- 5.2 percent***	- 4.5 percent

* Trend from 1974 – 2003; data collected prior to 1974 used inconsistent techniques and could not be included in the analyses.
** Inconsistent monitoring of leks precluded calculation of long-term annual rates of change.
***Trend from 1968 – 2003.

Connelly et al. (2004, p. 13-4), determined that of 41 populations delineated rangewide on geographical (not political) boundaries, 5 had been extirpated, 14 were at high risk of extirpation due to small numbers (only one active lek) and 12 additional populations also had small numbers (7 to 18 known active leks), including nine that were declining at a statistically significant rate. However, the remaining 10 populations contained the majority (92 percent) of the known active leks and were distributed across the current range.

In summary, since neither pre-settlement nor current numbers of sage-grouse are accurately known, the actual rate and magnitude of decline since pre-settlement times is uncertain. However, two independent groups of researchers with two different statistical methods that used lek counts as an index to relative abundance of greater sage-grouse concluded that rangewide greater sage-grouse have experienced long-term population declines in the past 43 years, with that decline lessening in the past 22 years.

Habitat and Floristic Management Zones

Sagebrush biology: Sagebrush is the most widespread vegetation in the intermountain lowlands in the western United States (West and Young 2000, p. 259). Scientists recognize many species and subspecies of sagebrush (Connelly et al. 2004, p.

5-2), each with unique habitat requirements and responses to perturbations (West and Young 2000, p. 259). Sagebrush species and subspecies occurrence in an area is dictated by local soil type, soil moisture, and climatic conditions (West 1983, p. 333; West and Young 2000, p. 260). The degree of dominance by sagebrush varies with local site conditions and disturbance history. Plant associations, typically defined by perennial grasses, further define distinctive sagebrush communities (Miller and Eddleman 2000, pp. 10-14; Connelly et al. 2004, p. 5-3), and are influenced by topography, elevation, precipitation and soil type.

All species of sagebrush produce large ephemeral leaves in the spring, which persist until soil moisture stress develops in the summer. Most species also produce smaller, over-wintering leaves in the late spring that last through summer and winter. Sagebrush have fibrous, tap root systems, which allow the plants to draw surface soil moisture, and also to access water deep within the soil profile when surface water is limited (West and Young 2000, p. 259). Most sagebrush flower in the fall. However, during years of drought or other moisture stress, flowering may not occur. Although seed viability and germination are high, seed dispersal is limited. Additionally, for unknown reasons, sagebrush seeds do not persist in seed banks beyond the year of their production (West and Young 2000, p. 260).

Sagebrush is long-lived, with plants of some species surviving up to 150 years (West 1983, p. 340). They produce allelopathic chemicals that reduce seed germination, seedling growth and root respiration of competing plant species and inhibit the activity of soil microbes and nitrogen fixation. Sagebrush has resistance to environmental extremes, with the exception of fire and occasionally defoliating insects (e.g., the webworm (*Aroga* spp.; West 1983, p. 341). Most species of sagebrush are killed by fire (Miller and Eddleman 2000, p. 17; West 1983, p. 341; West and Young 2000, p. 259). Natural sagebrush re-colonization in burned areas depends on the presence of adjacent live plants for a seed source or on the seed bank, if present (Miller and Eddleman 2000, p. 17).

Sagebrush is typically divided into two groups, big sagebrush and low sagebrush, based on their affinities for different soil types (West and Young 2000, p. 259). Big sagebrush species and subspecies are limited to coarse-textured and/or well-drained sediments, whereas low sagebrush subspecies typically occur where erosion has exposed clay or calcified soil horizons (West 1983, p. 334; West and Young 2000, p. 261). Reflecting these soil differences, big sagebrush will die if surfaces are saturated long enough to create anaerobic conditions for 2 to 3 days (West and Young 2000, p. 259). Some of the low sagebrush are more tolerant of occasionally supersaturated soils, and many low sage sites are partially flooded during spring snowmelt. None of the sagebrush taxa tolerate soils with high salinity (West 1983, p. 333; West and Young 2000, p. 257). Both groups of sagebrush are used by sage-grouse.

Sagebrush habitats vary widely within the extant range of the greater sage-grouse, as influenced by amount of precipitation, soil types, elevation, topography, and understory plant alliances (Miller et al., in press). Associated plant types show similar variability. For example, vascular plant species composition in sagebrush communities is strongly influenced by moisture availability and soil characteristics (Miller et al., in press). Production of annual herbaceous plants varies widely within and among communities due primarily to moisture availability, climate, soils, and topographic position. Forb abundance can be highly variable from year to year and is largely affected by the amount and timing of precipitation (Miller et al., in press). These ecological conditions influence the response and resiliency of sagebrush systems to natural and human-caused changes, management, and recovery. It is therefore inappropriate to assume that all sagebrush will respond to natural and human-caused changes in a consistent manner across the greater sage-grouse range. Restoration of sagebrush communities to pre-European settlement conditions is unlikely due to the size of the species range, the magnitude of existing changes, the loss of connectivity, and continual short and long-term changes in climate (Miller et al., in press).

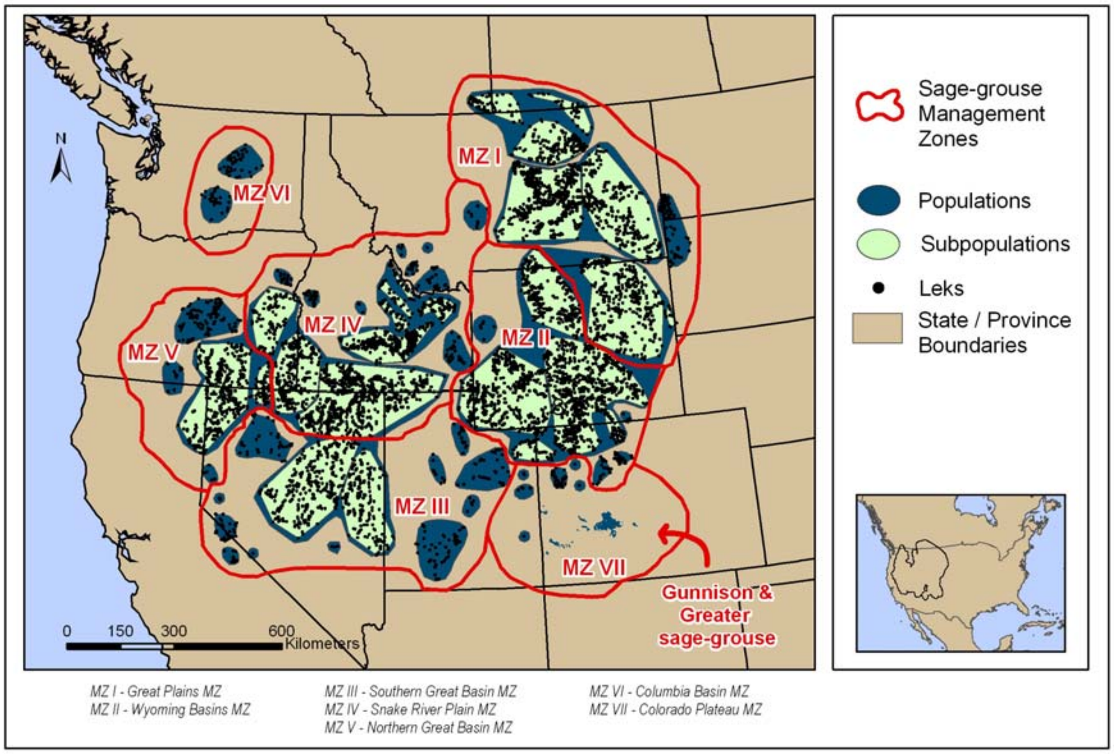
Management Zones: Due to differences in the ecology of sagebrush across the range of the greater sage-grouse, the Western Association of Wildlife Agencies (WAFWA) delineated seven Management Zones based primarily on floristic provinces (Figure 2; Table 3; Stiver et al. 2006, p 1-6). The boundaries of these management zones were delineated based on their ecological and biological attributes rather than on arbitrary political boundaries (Stiver et al. 2006, p. 1-6). Therefore, vegetation found within a management zone is similar and sage-grouse and their habitats within these areas are likely responding similarly to environmental factors and management actions.

Table 3: Management zones of the greater sage-grouse as defined by Stiver et al. (2006, pps. 1-17 and 1-13), and primary threats in each management zone.

Management Zone	States and Provinces included	Floristic Region	Primary Threat
I*	MT, WY, ND, SD, SK, AL	Great Plains	Energy development, habitat conversion, disease
II*	ID, WY, UT, CO	Wyoming Basin	Energy development, disease, habitat fragmentation
III	UT, NV, CA	Southern Great Basin	Invasive species, fire
IV*	ID, UT, NV, OR	Snake River Plain	Habitat conversion and fragmentation, disease,
V*	OR, CA, NV	Northern Great Basin	Invasive species, fire
VI	WA	Columbia Basin	Small population sizes, restricted habitats
VII	CO, UT	Colorado Plateau	Energy development, habitat fragmentation

*These zones contain the densest areas and core populations of sage-grouse, as defined by Connelly et al. 2004.

Figure 2: Management zones for the greater sage-grouse as identified by Stiver et al. (2006, p. 1-7); delineation primarily based on floristic provinces and population boundaries.



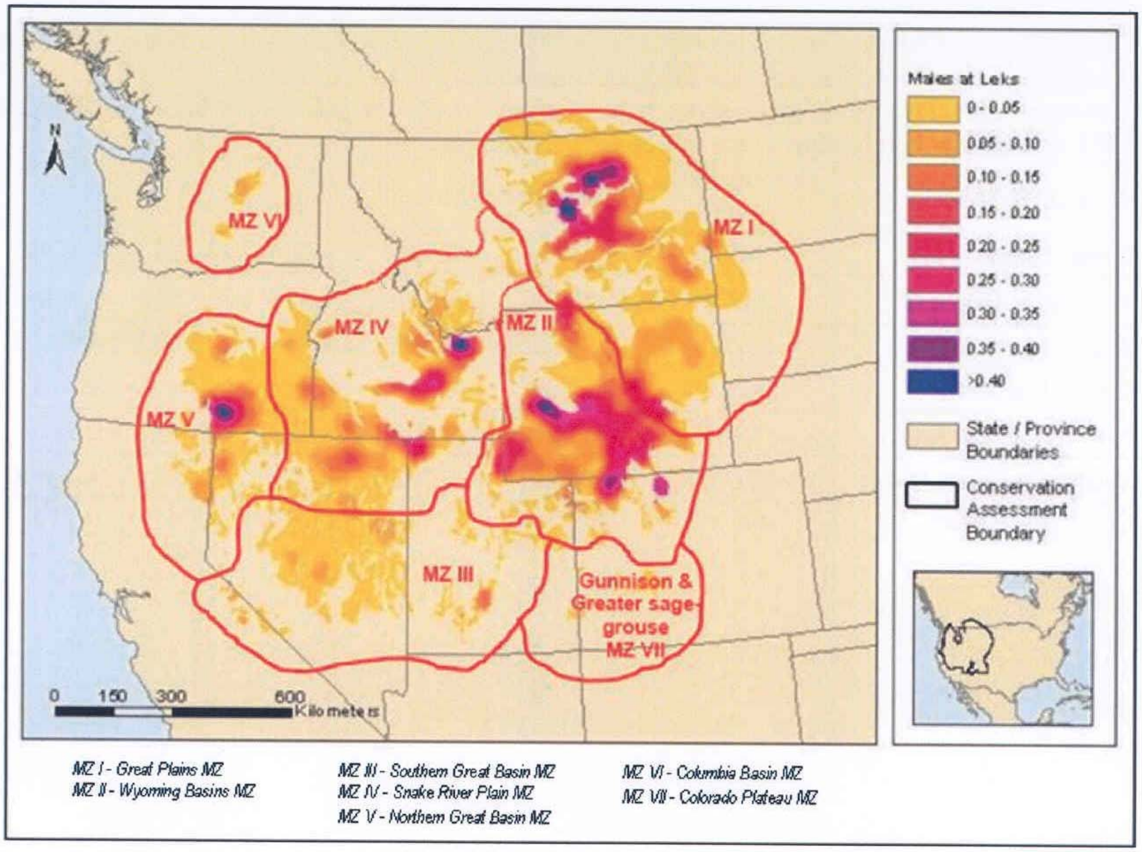
Management Zones I, II, IV, and V encompass the core populations of greater sage-grouse and have the highest reported densities (Table 4, Figure 3; Connelly et al. 2004). Management Zone III is composed of lower density populations in the Great Basin, while fewer numbers of more dispersed birds occur in Management Zone VI (Stiver et al, 2006, p. 1-7). Management Zone VII contains both greater and Gunnison sage-grouse on the Colorado Plateau (as noted previously, the two species do not have overlapping ranges).

Table 4: Relative abundance of greater sage-grouse leks, and number of males attending leks by management zone, based on the mean number of individual leks and mean maximum number of males attending leks by management one during 2005-2007.

Management Zone	Relative abundance of leks (2005 – 2007)	Relative abundance of males attending leks (2005-2007)
I	0.17	0.15
II	0.48	0.50

III	0.06	0.07
IV	0.19	0.18
V	0.09	0.10
VI	0.004	0.005
VII	0.003	0.003

Figure 3: Population densities based on average number of males per lek (taken from Connelly et al. 2004).



Differences in ecological conditions within each management zone affect the susceptibility of these areas to the various threats facing sagebrush ecosystems and its potential for restoration. For example, diffuse knapweed (*Centaurea diffusa*), an exotic annual weed, is most competitive within shrub-grassland communities where antelope bitterbrush is dominant (Management Zone VI), and cheatgrass (*Bromus tectorum*) is more dominant in areas with minimal summer precipitation (Management Zones III and V) (Miller et al, in press). Therefore, we stratify our analyses by these management zones because they represent zones within which ecological variation is less than what it would be across the range of the species. This will allow us to better assess the impact and benefits of actions occurring across the species range and in turn more accurately assess the status of the species.

Although the Management Zones were not formally adopted by WAFWA until 2006, the population trend analyses conducted by Connelly et al. (2004) included trend analyses based on the same floristic provinces used to define the zones. While the average annual rate of change was not presented, the results of those analyses suggested long-term declines in greater sage-grouse for Management Zones I, II, III, IV and VI. Population trends in Management Zones V and VII were increasing, but the trends were not statistically significant (Stiver et al.2006, p. 1-7). The WAFWA 2008 population trend analyses did consider management zones. They reported that Management Zones I-VI had negative population trends from 1965 – 2007, but there was no statistically detectable trend for Management Zone VII (WAFWA 2008, pps.13 – 27). Both population trend analyses had similar results (with the exception of Management Zone V)(Table 5). The authors of the 2008 WAFWA analysis did not offer an explanation of the differences between the two assessments for this management zone.

Table 5: Long-term population trend estimates for Greater sage-grouse management zones.

Management Zone	States and Provinces	Population Trend estimates, 1965-2003 (Connelly et al.	Population trend estimates based on annual rates of

	included	2004) *	change, 1965 - 2007 (WAFWA 2008)
I	MT, WY, ND, SD, SK, AL	Long-term decline	- 2.9 percent
II	ID, WY, UT, CO	Long-term decline	- 2.7 percent
III	UT, NV, CA	Long-term decline	- 2.2 percent
IV	ID, UT, NV, OR	Long-term decline	- 3.8 percent
V	OR, CA, NV	Change statistically undetectable	- 3.3 percent
VI	WA	Long-term decline	- 5.1 percent
VII	CO, UT	Change statistically undetectable	No detectable trend

*Average annual rate of change was not reported

The response of sagebrush and sagebrush ecosystems to natural and human-influenced disturbances varies based on the species of sagebrush and its understory component, as well as abiotic factors such as soil types and precipitation. For example, mountain big sagebrush can generally recover more quickly and robustly following disturbance than Wyoming big sagebrush (Miller and Eddleman 2000, p. 22), likely due to its occurrence on relatively moist, well drained soils, versus the very dry soils typical of Wyoming big sagebrush communities. Soil associations have also resulted in disproportionate levels of habitat conversion across different sagebrush communities. For example, basin big sage is found at lower elevations, in soils that retain moisture two to four weeks longer than in well drained, but dry and higher elevation soils typical of Wyoming big sagebrush locations. Therefore, sagebrush communities dominated by basin big sagebrush have been converted to agriculture more extensively than have communities on poorer soil sites (Winward 2004, p. 29).

Understanding how threats to the greater sage-grouse are influenced by differences in the sagebrush habitats (as defined by Management Zones) within the species' range allows us to more accurately assess the effects of these threats. In combination with population trend information, stratifying our assessment by management zone will greatly facilitate our understanding of long-term sage-grouse persistence.

Land Ownership and Management: Knick (2008, p. 30) estimated land ownership and management of the sagebrush lands within the sage-grouse management zones as follows: 31 percent private; 51 percent Bureau of Land Management (BLM); 8 percent U.S. Forest Service (USFS); 3 percent Bureau of Indian Affairs; 1 percent U.S. Fish and Wildlife Service (FWS); 1 percent all other Federal ownership combined; and 5 percent State ownership.

There are no special provisions for land management relevant to sage-grouse on private lands. Management of State lands is variable across the range, and many states have laws that influence the degree to which sage-grouse and sagebrush habitats factor into land management decisions. All eleven states across the current range of greater sage-grouse have final conservation or management plans for the species. These plans are in various stages of implementation, and generally contain information to help guide the development and execution of more focused conservation efforts and planning at a local level.

The Federal Land Policy and Management Act of 1976 (FLPMA) (43 U.S.C. 1701 et seq.) is the primary federal law governing most land uses on BLM-administered lands. Under guidance from FLPMA, the BLM prepares land use plans for resource management areas; there are currently 92 land use plans across the range of greater sage-grouse (BLM in litt. 2008a; p. 1). Land use plans are the basis for all actions and authorizations involving BLM-administered lands and resources: they establish allowable resource uses, resource condition goals and objectives to be attained; program constraints and general management practices needed to attain the goals and objectives; general implementation sequences; and intervals and standards for monitoring and evaluating the plan to determine its effectiveness and the need for amendment or revision (43 CFR 1601.0-5(k)). The BLM also has management and permitting authorities under the Mineral Leasing Act (MLA) (30 U.S.C. 181 et seq.) and the Regulations on Grazing Administration Exclusive of Alaska (43 CFR 4100). These authorities and their relevance to greater sage-grouse management are described in more detail in the Energy and Grazing sections below.

Management of federal activities on National Forest System lands is guided principally by the National Forest Management Act (NFMA) (16 U.S.C. 1600-1614, August 17, 1974, as amended 1976, 1978, 1980, 1981, 1983, 1985, 1988 and 1990). NFMA specifies that all National Forests must have a land and resource management plan (LRMP) (16 U.S.C. 1600) to guide and set standards for all natural resource management activities on each National Forest or National Grassland. The 1982 NFMA implementing regulation for land and resource management planning (1982 rule, 36 CFR 219), under which all existing forest plans were prepared, requires the Forest Service to manage habitat to maintain viable populations of existing native vertebrate species on National Forest System lands (1982 rule, 36 CFR 219.19). New land and resource management planning regulations were adopted on April 21, 2008 (36 CFR 219); all of the existing LRMPs within sage-grouse habitat will eventually be revised using the new planning rule. The Forest Service has additional authorities relevant to greater sage-grouse management under the On-Shore Oil and Gas Leasing Reform Act (1987; implementing regulations at 36 CFR 228, subpart E), which allows them to manage, restrict, or attach protective measures to mineral and other energy permits on USFS lands.

Greater sage-grouse are cooperatively managed by Provincial and Federal governments in Canada. The species is afforded Federal legal protection under schedule 1 of the Species at Risk Act (SARA; Canada Gazette, Part III, Chapter 29, Vol. 25, No. 3, 2002). Passed in 2002, the Species at Risk Act is similar to the Endangered Species Act and allows for habitat regulations to protect sage-grouse (Aldridge and Brigham 2003). The purpose of the SARA is to prevent the extinction or extirpation of any indigenous Canadian wildlife species, subspecies or distinct population segment, and to provide for the recovery of endangered or threatened wildlife (Connelly et al. 2004).

VULNERABILITY AND THREATS

The long-term persistence of greater sage-grouse is influenced by numerous natural and anthropogenic factors occurring within their range. Based on our experience with the 2005 finding, a continuing review of the scientific literature, and pertinent comments received from the public, we have identified the following threats to the greater sage-grouse and their habitats. These items are listed in no particular order. Where data were available, we have tried to link the threats to greater sage-grouse Management Zones so as to facilitate our understanding of the vulnerability of this species.

Habitat

Habitat—Fire

The effects of fire on sagebrush habitats, and therefore, their potential effects on sage-grouse, vary according to the species of sagebrush present, community association (e.g., understory type), and the severity, size, complexity, and intensity of the fire event.

Frequency of fire in sagebrush habitat: Widely variable estimates of mean fire return intervals are described in the literature: 10 to 70 years (Zouhar et al. 2008, p. 154), greater than 50 years for big sagebrush communities (McArthur 1994, p.347), 12 to 15 years for mountain big sagebrush (Miller and Rose 1999 p. 556), 20 to 100 years (Peters and Bunting 1994, p. 33), 10 to 110 years depending on sagebrush species and specific geographic area (Kilpatrick 2000, p. 1), and 13 to 25 years (Frost 1998 *in* Connelly et al.

2004, p. 7-4). In general, mean fire return intervals in low lying, xeric big sagebrush communities (*Artemisia tridentata* spp.) range from 100 to at least 200 years, and intervals decrease to decades in more mesic areas, higher elevations, and during wetter climatic periods (Baker 2006, p. 181; Mensing et al. 2006, p. 75; Miller et al., in press). There are inherent problems in understanding the historic fire regime in sagebrush communities due to the lack of fire scars, which are used to estimate historic fire return intervals. Thus, a clear picture of the complex spatial and temporal pattern of historic fire regimes in many sagebrush communities is not readily available.

Miller et al. (in press) summarized fire statistics for wildfires and prescribed fires that occurred within the sagebrush biome over the past century. From 1980 to 2007, the number of fires and total area burned increased in all Management Zones across the greater sage-grouse's range except the Snake River Plain (Management Zone IV). Average fire size only increased in the Southern Great Basin Management Zone (Management Zone III) during this period. Predicting the amount of habitat that will burn during an "average fire" year is difficult due to the highly variable nature of fire seasons. For example, the approximate area burned on or adjacent to BLM-managed lands varied from 140,000 ha (346,000 ac) in 1998 to a 6-fold increase in 1999 (814,200 ha; 2.0 million ac) to a 10-fold increase in 2006 (1.4 million ha; 3.5 million ac; Miller et al., in press).

Fire may affect the persistence of greater sage-grouse in the Great Basin (i.e., Utah, Nevada, Idaho, and eastern Oregon; Management Zones III, IV, and V), primarily due to the subsequent susceptibility of burned sites to invasion by exotic annual grasses. Wildfires have removed approximately 1.7 million ha (4.25 million ac) of sage-grouse habitat since 2003, or approximately 2.5 percent of extant habitat, and the trend in total acreage burned has increased since 1980 (Miller et al., in press). Although fire occurs throughout the greater sage-grouse's range, fire disproportionately affects the States of Idaho, Nevada, Oregon, and Utah. According to one review, range fires destroyed 30 to 40 percent of sage-grouse habitat in southern Idaho (Management Zone V) in a 5-year period (1997-2001; Signe Sather-Blair, BLM, *in* Healy 2001). This included about 202,000 ha (500,000 ac) which burned from 1999 to 2001; significantly affecting the largest remaining contiguous patch of sagebrush in the state. Between 2003 and 2007, Idaho lost about 267,000 ha (660,000 ac) of sage-grouse habitat or approximately 7 percent of the total estimated habitat in the state. Over the past 9 fire seasons in Nevada (1999-2007), about 1 million ha (2.5 million ac) of sagebrush habitats were burned; representing approximately 11 percent of extant sagebrush in the state (Espinosa and Phenix 2008, p. 3). Most of these fires occurred in northeast Nevada (Management Zone V) in fairly good habitat that has traditionally supported high densities of sage-grouse, and is most prone to cheatgrass invasion.

Effects of fire on sagebrush: In general, fire extensively reduces sagebrush within burned areas. Big sagebrush varieties, the most widespread species of sagebrush, are killed by fire, do not re-sprout after burning, and can take 30 to 50 years to re-colonize an area suggesting that these subspecies evolved in an environment where wildfire was infrequent and patchy (Braun 1998, p. 9). The patchy historic fire pattern in sagebrush communities, particularly in Wyoming big sagebrush (*A. tridentata* var. *wyomingensis*), was due to discontinuous and limited fine fuels (i.e., grasses), resulting in a mixed severity-stand replacing fire regime (Miller and Eddleman 2000, p. 16; Zouhar et al. 2008, p. 154). Natural fires typically resulted in incomplete burning of large expanses of habitat, leaving islands of unburned vegetation. These islands promoted future re-colonization of the sagebrush communities by providing sources of sagebrush seed (Huff and Smith 2000, p. 39).

Invasions by other species: Woodlands can encroach into sagebrush communities when fire return intervals are long enough to allow for seedling establishment and tree maturation (see the pinyon-juniper discussion below). In parts of the Great Basin (i.e., Nevada, Oregon and Utah) a decline in fire occurrence since the late 1800s has been reported in several studies, with an immediate widespread decline in fires coinciding with the introduction of large numbers of livestock and active fire suppression efforts (Touchan et al. 1995, p. 272; Miller and Rose 1999, p. 558; Miller et al., in press). The probability that woody conifer species, such as western juniper (*Juniperus occidentalis*), will displace sagebrush communities increases where seed sources are nearby and fire intervals increase to 50 to 100 years.

Alternatively, invasion of exotic annuals, such as cheatgrass (*Bromus tectorum*) and medusahead (*Taeniatherum asperum*), increase fire frequency within the greater sage-grouse's range (Miller et al., in press; Zouhar et al. 2008, p. 41). Cheatgrass readily invades sagebrush communities, especially disturbed sites and changes historic fire patterns by providing an abundant fine fuel source that facilitates fire spread. While sagebrush is killed by fire and only regenerates from seed (given an available source), cheatgrass recovers within 1 to 2 years of a fire event (Young and Evans 1978, p. 285). It is difficult and usually ineffective to restore an area to sagebrush after annual grasses becomes established (Paysen et al. 2000, p. 154; Connelly et al. 2004, pp. 7-44 to 7-50; Davies 2008, pp. 110-111). Habitat loss from fire and the subsequent invasion by non-native annual grasses has negatively affected sage-grouse populations (Connelly et al. 2000c, p. 93).

Evidence exists of a relationship between fire locations and cheatgrass distribution in the Snake River Plain (Management Zone IV) and Northern Great Basin (Management Zone V) since the 1960s (Miller et al., in press), and in northern Nevada and eastern Oregon since 1980 (Management Zone V) . At least partially as a result of the relationship between wildfire and the spread of invasive plants, approximately 29 million acres of public lands in the western distribution of the greater sage-grouse (i.e., Washington, Oregon, Idaho, Nevada, Utah) were estimated to be invaded with weeds in 2000 (BLM 2007, p. 3-43); and specifically cheatgrass is currently present throughout much of the western United Sates.

Effects of fire on invertebrates: In addition to altering plant community structure, fires influence invertebrate food supplies, which are an essential component of juvenile sage-grouse diets (Schroeder et al. 1999, p. 5). Along with plant community effects, invertebrate food supplies are another habitat element influenced by fire. Ants

(Hymenoptera), grasshoppers (Orthoptera), and beetles (Coleoptera) are important in the diet of juvenile sage-grouse, especially in the first three weeks of life (Schroeder et al. 1999, p. 5). Crawford and Davis (2002, p.56) reported that the abundance of arthropods did not decline following wildfire, and Pyle (1992, p. 14) reported that there was no apparent effect of prescribed burning to beetles. However, other studies found that the abundance of insects was significantly lower 2 to 3 years post-burn (Fischer et al. 1996, p. 197). Additionally, grasshopper (Orthoptera) abundance declined 60 percent in burned plots versus unburned plots one year post-burn, but this difference disappeared the second year (Bock and Bock 1991, p. 165). Conversely, Nelle et al. (2000, p. 589) reported the abundance of beetles and ants was significantly greater in 1-year old burns, but returned to pre-burn levels by years 3 to 5. Grasshopper abundance (both adult and nymph) declined by 60 percent on burned plots versus unburned plots by the first year after fire, but the differences disappeared in the second year (Bock and Bock 1991, p. 165). Fire effects to insects probably vary due to plant communities, time of year when burned, and insect population level pre-fire. Because few studies have been conducted and the results of those available vary, the specific magnitude and duration of the effects of fire on insect communities is still uncertain, as is the effect any changes may have on for sage-grouse.

Effects of fire on understory: The response of sagebrush understory to fire varies with differences in topography, existing fuel load, moisture content of vegetation and soil, fire severity, season of burn, and succeeding climatic conditions, among other factors. In general, when not considering the synergistic effects of invasive species, short-term studies report varied responses by grasses and forbs to fire and longer data sets (5 or more years) suggest little difference in the response of understory to fire between control and treatment sites (Nelle et al. 2000, p. 588). For example, Wrobleski (1999, p. 31) reported increased forb production, but decreased perennial grasses in burned versus control plots. Payson et al. (2000, p. 154) also noted little recruitment of perennial grasses within the first 3 to 5 years post-fire, although remnant forbs and grasses increased biomass production. In another study, perennial herb productivity was 2.2 times higher on burned versus control areas by the second year post-burn (Cook et al. 1994, p. 298). However, Crawford (1999, p. 7) observed little change in species composition between unburned and burned areas after a 1998 prescribed burn in Oregon. Fischer et al. (1996, p. 196) also noted that vegetation used in sage-grouse diets was similar in unburned and burned habitat. In a review of 13 sites that burned over 2 to 32 year-span, Wambolt et al. (2001, p. 250) found that burns did not assist perennial grass and forb production.

Restoration of sagebrush habitat: A variety of techniques have been attempted to re-establish sagebrush post-fire, with mixed success (Cadwell et al. 1996 p. 143, Quinney et al. 1996 p. 157, Livingston 1998 p. 41). Sagebrush restoration efforts following a fire are complicated by the presence of invasive exotic annual plant species, cost associated with activity, availability of suitable seeds, and difficulty associated with establishing sagebrush seedlings. Still, habitat rehabilitation following fires has become a major activity in recent years, increasing from 28,100 ha (69,436 ac) in 1997 to 1.6 million ha (3.9 million ac) in 2002 with most treatments in Oregon, Idaho, and Nevada (Connelly et al. 2004, pp. 7-35). Although not all burned habitat is rehabilitated, fires which occur on pubic lands will experience some degree of post-fire restoration. For example, of the more than 1 million ha (2.5 million ac) of sage-grouse habitat burned during the 2006 and 2007 fire seasons on BLM-managed lands, about 40 percent or 384,000 ha (950,000 ac) had some form of post-fire restoration. Still, the efficacy of these efforts and the utility of these sites for sage-grouse in the future will not be realized for several decades.

Effects of fire on sage-grouse: The response of greater sage-grouse to fire has not been clearly demonstrated (Braun 1998, p. 9) and the majority of studies suggest fire negatively impacts sage-grouse. Several studies have indicated that fire can improve brood-rearing habitat (Klebenow 1970, p. 399; Pyle and Crawford 1996, p. 323; Gates 1983 *in* Connelly et al. 2000c, p. 90; Sime 1991 *in* Connelly et al. 2000a, p. 972). Also, Slater (2003, p. 63) reported that sage-grouse using burned areas were rarely found more than 60 m (200 ft) from the edge of the burn, further the researcher suggests a preferential use of the burned/unburned edge habitat.

Fires can cause adverse conditions where cover is limited (Call and Maser 1985, p. 17). For example, prescribed fires in mountain big sagebrush at Hart Mountain National Antelope Refuge caused a short-term increase in certain forbs, but reduced sagebrush cover, potentially making habitat less suitable for nesting and brood rearing (Rowland and Wisdom 2002, p. 28). Similarly, Nelle et al. (2000, p. 586) and Beck et al. (2008, p. 8) reported nesting and brood rearing habitat loss from fire, creating a long-term negative impact that will require 3 decades of sagebrush re-growth before sufficient canopy cover becomes available for nesting birds.

Data collected at 24 burned sites in Montana between 4 and 67 years post-fire, suggest recovery of Wyoming big sagebrush likely requires well over 100 years (Cooper et al. 2007, p. 13). The Montana study is further supported by a recent meta-analysis that suggests mountain big sagebrush (*A. t. var. vaseyana*) recovers within 35 to at least 100 years, while Wyoming big sagebrush requires 50 to at least 120 years to recover (Baker 2006, p. 177).

Byrne (2002, p. 27) reported avoidance of burned habitat by nesting, brood-rearing, and broodless females and both Connelly et al. (2000c, p. 90) and Fischer et al. (1996, p. 196) found that prescribed burns did not improve brood rearing habitat in Wyoming big sagebrush, as forbs did not increase and insect populations declined as a result of the treatment. Hence, fire in this sagebrush type may negatively affect brood rearing habitat rather than improve it (Connelly and Braun 1997, p. 11). In southeastern Idaho, Connelly et al. (2000c, p. 93) concluded that, sage-grouse populations were declining across the study area, but declines were more severe in post-fire years. Fischer et al. (1997, p. 89) concluded that fire-caused habitat fragmentation may influence distribution or migratory patterns in sage-grouse, and Hulet (1983, *in* Connelly et al. 2000a, p. 973) documented the loss of leks from fire.

Summary (Habitat--Fire): The specific response of insects and the sagebrush understory, which both are food resources for sage-grouse, are not well-understood. In addition, the specific response of sage-grouse to fire has not been clearly demonstrated. However, fire can reduce the amount of sagebrush habitat available to sage-grouse and that this habitat, once burned, is slow to regenerate and problematic to restore. Fire can also promote invasion of non-native plants (e.g., cheatgrass) which are difficult to control and which increase the likelihood of fires in the future.

Measures for minimizing fire effects: Knick (2008, p. 30) estimates that about 51 percent of sagebrush habitat within the sage-grouse management zones is BLM-administered land; this includes approximately 24.9 million ha (about 61.5 million acres). The BLM reports that 92 of their Land Use Plans (LUPs) occur within sage-grouse habitats and that 82 of these contain specific measures or direction pertinent to management of sage-grouse or their habitats (BLM in litt. 2008a, p. 1; BLM in litt 2008b). Of these 82 LUPs, 37 contain specific provisions pertaining to wildfire and fuels management as it relates to sage-grouse or sagebrush habitat. Provisions vary by LUP and in large part there are not consistent measures which address sage-grouse across their range. Specific LUP objectives include prevention of large scale fires through the creation of fuel breaks or suppression; rehabilitation of habitats following fire through reseeding and use restrictions; and restoration of degraded habitats through prescribed burning, “let burn”, or mechanical treatments intended to reset the successional stage of the vegetation community.

One notable recent action adopted on a rangewide scale is BLM's National Instructional Memo (IM) 2008-142 – 2008 Wildfire Season and Sage-Grouse Conservation. This IM was issued on June 19, 2008, and is effective through September 30, 2009. It provides guidance to BLM State Directors that conservation of greater sage-grouse and sagebrush habitats should be a priority for wildfire suppression, particularly in areas of the great basin (WAFWA Management Zones III, IV, and V) (BLM IM 2008-142, June 19, 2008). At least one BLM state office within the range of sage-grouse (Idaho) has developed a state-level IM and guidance that prioritizes the protection of sage-grouse habitats during fire management activities, in addition to the national IM which pertains to wildfire suppression activities (BLM IM 2008-051, June 6, 2008). The extent to which these directives will alleviate the threat of wildfire to sage-grouse is not known, nor is it known whether this guidance will be applied into the future, i.e. after the IM expires. The BLM's IM 2008-142, which elevates the priority of important sage-grouse habitat during wildfire control and focuses fire control resources, is an effort that could provide benefits to sage-grouse over time if it is extended.

The Forest Service has management responsibility for approximately 8 percent of sagebrush habitats in the U.S., most of which are located at higher elevations in Nevada, Idaho, and Oregon, and largely consisting of montane or low sagebrush communities (Knick 2008, p. 14). Of the 24 National Forests within the sage-grouse range which address sage-grouse in their Forest Plans, direction for the conservation of sage-grouse and their habitats relative to fire and fuels management was provided in 18 (USDA Forest Service *in litt*, 2004). Language and goals outlined in specific Forest Plans vary but are largely informed by habitat recommendations outlined in Connelly et al. (2000). The effectiveness of the Forest Plan regulations for the conservation of sage-grouse and their habitats was not reported by the USFS.

Five percent of sagebrush habitats are managed by state agencies (Knick 2008, p. 14). Using a variety of funding sources, state agencies (especially Utah, Idaho, Nevada, and Oregon) work toward preventing, and rehabilitating sagebrush habitats influenced by fire. For example, Utah's Watersheds Restoration Initiative is a partnership driven effort which actively funds projects intended to conserve, manage, and restore habitats. Although these activities are not driven by a regulatory mechanism, they still provide substantial conservation benefit. Excluding lands managed by the BLM, about 13,000 ha (33,000 ac) of sage-grouse habitat was treated as part of a fire management policy by state and federal agencies since 2005. Treatments varied (e.g., mechanical, prescribed fire, herbicide) but all acreages reported were intended to provide a net benefit to sage-grouse. The effectiveness of these treatments is not currently known. Thirty-one percent of sagebrush habitat occurs on privately owned lands (Knick 2008, p. 30). No specific regulatory mechanisms apply to sagebrush habitats occurring on private lands.

Habitat—Invasive plants (annual grasses/other noxious weeds)

Several widely-accepted definitions exist for invasive plants, (also called invasives) (Randall et al. 2008, p. 37). In this review, we consider invasives to be any non-native plant that negatively impacts the biodiversity of sage-grouse habitat. Invasives alter plant community structure and composition, productivity, nutrient cycling, and hydrology (Vitousek 1990, p. 7) and may cause declines in native plant populations through competitive exclusion and niche displacement, among other mechanisms (Mooney and Cleland 2001, p. 5446). A variety of non-native annuals and perennials are invasive to sagebrush ecosystems (Connelly et al. 2004, pp. 7-107 and 7-108; Zouhar et al. 2008, p 144) and can reduce or eliminate vegetation that sage-grouse use for food and cover.

Noxious weeds spread about 931 ha (2,300 ac) per day on BLM land and 1,862 ha (4,600 ac) per day on all public land in the West (BLM 1996, p. 1), or about 8-20 percent annually (Federal Interagency Committee for the Management of Noxious and Exotic Weeds 1997, p. v). Invasions are often associated with ground disturbances caused by wildfire, grazing, infrastructure, and other anthropogenic activity (Rice and Mack 1990, p. 84; Gelbard and Belnap 2003, p. 420; Zouhar et al. 2008, p. 23), but disturbance is not required for invasives to spread (Young and Allen 1997, p. 531, Roundy et al. 2007, p. 614). Invasions may also occur sequentially, where initial invaders (e.g., cheatgrass) are replaced by new exotics (Crawford et al. 2004, p 9; Miller et al., in press).

Annual grasses: Annual grasses (e.g., cheatgrass and medusahead) impact sagebrush ecosystems by shortening fire intervals to approximately 5 years, perpetuating their own persistence and intensifying the role of fire (Braun 1998, p. 9; Connelly et al. 2004, pp. 5-10 and 7-14). Annual grasses have caused extensive sagebrush habitat loss in the Intermountain West and Great Basin (Connelly et al. 2004, pp. 1-2 and 4-16). Although they occur throughout the sage-grouse's range, they are considered more problematic in western states (Management Zones III, IV, and V) than Rocky Mountain states (Montana, Wyoming, and Colorado; Connelly et al. 2004, p. 5-9). Cheatgrass is considered most invasive in Wyoming big sagebrush communities, while medusahead fills a similar niche in more mesic communities with heavier clay soils (Connelly et al. 2004, p. 5-9).

Approximately 80 percent of land in the Great Basin is susceptible to displacement by cheatgrass (including over 65 percent that is moderately or highly susceptible) within 30 years (Management Zones III, IV, and V) (Connelly et al. 2004, p. 7-17). Although the Great Basin appears more susceptible to cheatgrass invasion than other parts of the sage-grouse's range, Connelly et al. (2004, p. 7-8) cautioned that a formal analysis of the risk of cheatgrass invasion in other areas was needed before such inferences are made. Also, while annual grasses are usually associated with lower elevations and drier climates (Connelly et al. 2004, p. 5-5), the ecological range of cheatgrass continues to expand at low and high elevations (Ramakrishnan et al. 2006, pp. 61-62), both southward and eastward (Miller et al., in press). There are local infestations of cheatgrass and other annual grasses in Montana, Wyoming, and Colorado (Management Zones I and II) (Miller et al., in press), and there is evidence that cheatgrass is impacting fire intervals in Wyoming. For example, 40,469-ha (100,000-ac) of sagebrush that burned in a wildfire southeast of Worland, Wyoming (Management Zone II) became infested with cheatgrass, accelerating the fire interval in this area (Wyoming Big Horn Basin Sage-grouse Local Working Group 2007, p. 39-40).

Distribution of invasives: Quantifying the total acres of sage-grouse habitat impacted by invasives is problematic due to differing sampling methodologies, incomplete sampling, inconsistencies in species sampled, and varying interpretations of what constitutes an infestation (Miller et al., in press). Furthermore, Connelly et al. (2004, p. 5-10) noted that several prominent publications have incorrectly stated that cheatgrass dominates 40 million ha (98.8 million ac) in the West. This estimate is a mis-quote from a publication that stated cheatgrass dominated many rangelands within the 41 million ha (101 million ac) of potential steppe vegetation in the Intermountain West (Connelly et al. 2004, p. 5-10).

Widely variable estimates of the total acreage of weed infestations have been reported. BLM (1996, p. 6) estimated invasives covered at least 3.2 million ha (8 million ac) of BLM lands as of 1994, and predicted 7.7 million ha (19 million ac) would be infested by 2000. However, a qualitative 1991 BLM survey covering 40 million ha (98.8 million ac) of BLM-managed land in Washington, Oregon, Idaho, Nevada, and Utah (Management Zones III, IV, V, and VI) reported that annual grasses were a dominant or significant presence on 7 million ha (17.2 million ac) of sagebrush ecosystems (Connelly et al. 2004, p. 5-10). An additional 25.1 million ha (62 million ac) had less than 10 percent cheatgrass in the understory, but were considered to be at risk of cheatgrass invasion (Zouhar 2003, p. 3, in reference to the same survey). More recently, BLM reported that, as of 2000, noxious weeds and annual grasses occupied 11.9 million ha (29.4 million ac) of public lands in Washington, Oregon, Idaho, Nevada, and Utah (BLM 2007, p. 3-28). However, when considering all states within the current range of sage-grouse, this number increases to 14.8 million ha (36.5 million ac.).

The Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) has the most complete rangewide dataset documenting annual grass distribution. Based on 1999- 2002 imagery, there are at least 426,931 ha (1.1 million ac) of annual grasses in the 7 management zones (Stiver et al. 2006, p. 1-11; LANDFIRE 2007). This is a gross underestimate of the total acres of infestation. Satellite data only map annual grass monocultures, and not areas where they occur in lower densities or even dominate the sagebrush understory (which is mapped as sagebrush). However, this information provides a rangewide comparison of annual grass monocultures. A little over half of all mapped annual grass acreages occur in Management Zones III and IV. The number of acres for the four other zones were similar (Stone 2008), indicating that parts of Montana and Wyoming contain similar amounts of annuals as Washington, south-central Oregon, and northwest Nevada. Based on data collected in the western half of the range, Bradley et al. (in press 2008, pp. 41-43) predicted favorable conditions for cheatgrass rangewide under current and future (2100) climate conditions. However, she predicts that some areas will become unfavorable while others become favorable.

Habitat restoration: Restoration or rehabilitation of areas to sagebrush after invasives, particularly annual grasses, become established is very difficult (see discussion on fire above). For example, only 10 to 50 percent of recent vegetation treatments conducted by the BLM in annual grassland monocultures and in sagebrush habitats with predominantly annual grass understories were reported as successful (Carlson 2008b). Often treatment success depends on factors which are not controllable such as precipitation received at the treatment site.

Effect of invasives on sage-grouse: Invasives are a rangewide threat, and one of the highest extinction risk factors for sage-grouse based on their ability to out-compete sagebrush, the inability to effectively control them once they become established, and the synergistic interaction between them and other risk factors on the landscape (e.g., wildfire, infrastructure construction). There have been many studies addressing effective invasive control methods, as well as conservation actions to control invasives, with varied success. While some efforts appear successful at smaller scales, prevention appears to be the only known effective tool to preclude large-scale habitat loss from invasive species in the future.

Habitat—Pinyon-juniper encroachment

Pinyon-juniper woodlands are a native habitat type dominated by pinyon pine (*Pinus edulis*) and various juniper species (*Juniperus* spp.) that can encroach upon and infill sagebrush habitat. Pinyon-juniper woodlands are often associated with sagebrush communities and currently occupy at least 18 million ha (44.6 million ac) of the Intermountain West, within the sage-grouse's range (Crawford et al. 2004, p. 8; Miller et al. 2008, p. 1). Pinyon-juniper extent has increased 10-fold in the Intermountain West since European settlement causing the loss of many bunchgrass and sagebrush-bunchgrass communities (Miller and Tausch 2001, pp. 15, 16). This expansion has been attributed to decreased fire return intervals in big sagebrush habitat as a result of livestock grazing (which reduces fine fuels; (Miller and Tausch 2001, p. 15). It has also been suggested that increases in global carbon dioxide concentrations and climate change may influence woodland expansion (Miller and Rose 1999, pp. 555-556; Miller and Tausch 2001, p. 15).

Connelly et al. (2004, pp. 7-8 to 7-14) estimated the risk of sagebrush displacement by pinyon-juniper within 30 years for a large portion of the Great Basin, based on site elevation, proximity to extant pinyon-juniper, precipitation, and topography. Approximately 60 percent of sagebrush in the Great Basin was at low risk, 6 percent at moderate risk, and 35 percent was at high risk of displacement (Connelly et al. 2004, pp. 7-12 to 7-14). Mountain big sagebrush appears to be most at risk of pinyon-juniper displacement (Connelly et al. 2004, pp. 7-13). When juniper increases in mountain big sagebrush communities, shrub cover declines and the season of available succulent forbs is shortened due to soil moisture depletion (Crawford et al. 2004, p. 8). As with cheatgrass, the Great Basin (Management Zones III, IV, and V) appears more susceptible to pinyon-juniper invasion than other areas of the sage-grouse's range; however, Connelly et al. (2004, pp. 7-8) cautioned that a formal analysis of the risks posed in other locations was needed before such inferences could be made.

Pinyon-juniper expansion into sagebrush habitats, with subsequent replacement of sagebrush shrub communities has been well documented (Miller et al. 2000, p. 575; Crawford et al. 2004, p. 2; Connelly et al. 2004, pp. 7-5; Miller et al. 2008, p. 1). However, few studies have documented woodland dynamics at the landscape level across different ecological provinces, creating some uncertainty regarding the total amount of expansion that has occurred in sagebrush communities (Miller et al. 2008, p. 1). Regardless, we know that up to 90 percent of existing woodlands currently occupy sites previously dominated by sagebrush vegetation prior to the late 1800s (Miller et al., in press). Additionally, expansion will likely continue at varying rates across the landscape and cause further loss of sagebrush habitat within the western part of the sage-grouse's range, especially the southern Great Basin (Management Zone III).

While pinyon-juniper appears less problematic in the eastern portion of the range (Management Zones I, II and VII) and silver sagebrush areas, woodland encroachment is a threat mentioned in Wyoming, Montana, and Colorado state sage-grouse plans, indicating that this is of some concern in these states as well (Stiver et al. 2006, p. 2-23). Colorado's state plan mapped areas threatened by pinyon-juniper encroachment in northwest Colorado, and specifically attributed some sage-grouse habitat loss in Colorado to pinyon-juniper expansion (Colorado Greater Sage-grouse Steering Committee 2008, pp. 179, 182). Furthermore, LANDFIRE (2007) data illustrates extensive coverage of pinyon-juniper woodlands in parts of northwest Colorado within the range of sage-grouse. This data also shows limited pinyon-juniper coverage in Montana and Wyoming; however, LANDFIRE data could be a major underestimate of juniper because is difficult to classify pinyon-juniper woodlands with satellite imagery when it occurs at low densities (Hagen 2005, p. 142).

Effects of pinyon-juniper on sage-grouse: Commons et al. (1999, p.238) found that the number of male Gunnison sage-grouse on leks in southwest Colorado doubled after pinyon-juniper removal and mechanical treatment of mountain sagebrush and deciduous brush. Hence we infer that some greater sage-grouse populations have been affected and some will decline due to projected increases in the pinyon-juniper type, at least within parts of the Great Basin (Management Zones III and IV). Doherty et al. (2008, p. 187) reported a strong avoidance of conifers by female greater sage-grouse in the winter, further supporting our previous inference.

In 2005, we considered pinyon-juniper a high extinction risk for sage-grouse in the western and low risk in the eastern portions of its range. Since 2005, many conservation actions have addressed this threat using a variety of techniques (e.g., mechanical, herbicide, cutting, burning) to remove conifers in sage-grouse habitat. The effectiveness of these treatments varies with the technique used and proximity of the site to invasive plant infestations, among other factors. We are not aware of any study documenting a direct correlation between these treatments and increased greater sage-grouse productivity; however, we again infer a positive response based on Commons et al.’s (1999) Gunnison sage-grouse study. Instead, effectiveness of treatments for greater sage-grouse is usually based on a short-term, anecdotal evaluation of whether pinyon-juniper was successfully removed from a site. It is still too early to measure a population response to these treatments (ODFW in litt. 2008, p. 3). Consequently, we do not know if these efforts are effectively ameliorating the threat of pinyon-juniper expansion. Furthermore, while many acres have been treated since 2004 (21,598 ha (53,369 ac) on BLM lands and 32,824 ha (81,110 ac)on other lands, treatments are not likely keeping pace with the current rate of pinyon-juniper encroachment, at least in parts of the range.

Measures for minimizing invasives and pinyon-juniper effects: There are numerous statutes, directives, regulations, policies, and guidance documents encouraging invasive plant control at local, state, and national scales. The Federal Noxious Weed Act (FNWA) of 1974 gave the Secretary of Agriculture authority over noxious weed movement into and within the United States. This Act was amended in 1990, requiring federal land management agencies to fund noxious weed control programs in cooperation with states. In 2000, The Plant Protection Act superseded most of the FNWA; however, noxious weed movement is still regulated by the Secretary of Agriculture and the 1990 amendment is still in effect.

More recently, there has been an increased focus on the roles that state, county, and private entities have in controlling invasive plants. For example, The Noxious Weed Control and Eradication Act was passed in 2004 and incorporated into the Plant Protection Act. This Act is intended to assist eligible weed management entities to control or eradicate harmful non-native weeds on both public and private lands. Additionally, Executive Order 13112 was signed on February 3, 1999, establishing an interagency National Invasive Species Council in charge of creating and implementing a National Invasive Species Management Plan. The Management Plan directs federal efforts, including overall strategy and objectives, to prevent, control, and minimize invasive species and their impacts (National Invasive Species Council 2008, p. 5). However, the Order also directs the Council to encourage planning and action at local, tribal, state, regional, and eco-system levels to achieve the goals of the National Invasive Species Management Plan, in cooperation with stakeholders (e.g., private landowners, states) and existing organizations addressing invasive species. The Council currently consists of 13 Departments and Agencies, and has recently completed their 2008-2012 Management Plan. The specific implementation of tasks and performance elements within this plan depends upon agency budgets, and in some cases, legal or regulatory changes (National Invasive Species Council 2008, p. 5).

One of the most common forms of noxious and invasive weed treatments on BLM lands is reseeding through the Emergency Stabilization and Burned Area Rehabilitation Programs. According to BLM data collected in a FY 2006-2007 data call, 66 of 92 Resource Management Plans (RMPs) responding to the data call noted that seed requirements (as stated in RMPs, emergency stabilization and rehabilitation, and other plans) were sufficient to provide suitable sage-grouse habitat (e.g., seed containing sagebrush and forb species). However, a sufficient seed mix does not guarantee that restoration goals will be met, as there are many other factors (e.g., precipitation) influencing the outcome of restoration efforts. Still, invasive species control is a priority for many RMPs. For example, 76 of the RMPs that responded to the data call claim that the RMP (or supplemental plans/guidance applicable to the RMP) require treatment of noxious weeds on all disturbed surfaces to avoid infestations of BLM-managed lands in the planning area. Also, of the 82 RMPs that reference sage-grouse conservation, 51 of these specifically address either fire, invasives, or conifer encroachment issues, or a combination thereof (Carlson 2008a). We also note that it is possible that more RMPs are specifically addressing invasives under another general restoration category.

Herbicides are also commonly used on BLM lands to control invasives. In 2007, the BLM completed a programmatic Environmental Impact Statement, report (72 FR 35718) and Record of Decision (72 FR 57065) for vegetation treatments on BLM-administered lands in the western United States. This program approves the use of four new herbicides, provides and updated analysis of 18 currently used herbicides, and identifies herbicides that the BLM will no longer use on public lands. It guides the use of herbicides for field-level planning, but does not authorize any specific on-the-ground actions; site-specific NEPA analysis is still required at the project level. Since the BLM reported restoration actions from Fiscal Years 2006 and 2007 (ending October 2007), we do not have information on how much the programmatic EIS has been used for most states, or whether actions implemented under this EIS have been effective. Oregon has not implemented actions under this EIS because the Oregon BLM is preparing a separate, statewide programmatic EIS that will tier to and adopt procedures from the western states' programmatic EIS (73 FR 35408). This is being done in part to address issues specific to a 1984 injunction that prohibited herbicide use in Oregon.

Some States require landowners to control noxious weeds on their property, but the types of plants considered to be noxious weeds vary by state. For example, only Oregon, California, Colorado, Utah, and Nevada list medusahead as a noxious, regulated weed, but medusahead can be problematic in other states (e.g., Washington, Idaho). The only western State that officially lists cheatgrass as a noxious weed is Colorado (http://plants.usda.gov/java/noxiousDriver), but cheatgrass in invasive in many more states. Although individual States have regulations regarding invasive species, we were unable to determine how these regulations affect sage-grouse habitats.

Several non-regulatory tools and mechanisms exist that can be used to address invasive species concerns. The rangewide conservation assessment and strategy for sage-grouse identifies specific objectives and goals to address invasive species, and identifies responsible parties and costs associated with implementing these goals (Stiver et al. 2006, p. 9-11 to 9-12). Additionally, goals (some general and some more specific) are identified in state and local sage-grouse management plans to address invasive species concerns that are implemented (to varying degrees) by state- and local- working groups.

Another voluntary approach to control invasives is the development of Cooperative Weed Management Areas (CWMAs). CWMAs are partnerships between federal, state, and local agencies, tribes, individuals, and interested groups to manage both regulatory noxious weeds and invasive plants in a county or multi-county geographical area. They function under a mutually developed memorandum of understanding and a locally developed strategic plan. The CWMAs can utilize federal funds for invasive plant control on non-federal land. As of 2005, Oregon, Nevada, Utah, and Colorado had between 75 and 89 percent of their states covered by CWMAs and/or county weed districts, while Washington, Idaho, Montana, and Wyoming had between 90 and 100 percent coverage. Coverage in North Dakota is between 50 and 74 percent, and South Dakota has less than 25 percent coverage (Center for Invasive Plant Management 2008 http://www.weedcenter.org/weed_mgmt_areas/wma_overview.html).

In summary, there are many regulatory mechanisms and non-regulatory measures to control invasive plants. However, the extent that these mechanisms effectively ameliorate the current rate of invasive expansion is unclear. If noxious weeds are spreading at a rate of 931 ha (2,300 ac) per day on BLM lands (BLM 1996, p. 1), this amounts to 339,815 ha (839,500 ac) per year, which includes both suitable and non-habitat for sage-grouse. It is unclear whether this estimate is limited to noxious weeds or if includes other invasives (e.g., cheatgrass). Still, we can compare this estimate to the acres treated by BLM in between October 2005 and September 2007; 298,676 ha

(738,042 ac). It is unlikely that conifer encroachment was included in the estimated rate of noxious weed spread that was reported by BLM (1996, p. 1).

The National Invasive Species Council (2008, p. 8) acknowledges that, "despite the significant increase in activity and awareness, much remains to be done to prevent and mitigate the problems caused by invasive species." As an example, the state of Montana has made much progress through partnerships in reducing noxious weeds in the state from 8 million ac in 2000 to 7.6 million in 2008 (Montana Weed Control Association in litt. 2008). However, the Montana Noxious Weed Summit Advisory Council Weed Management Task Force (2008, p. III) estimates that to slow weed spread and reduce current infestations by 5 percent annually, they require 2.6 times the current level of funding from a variety of private, local, state, and federal sources (or $55.8 million versus $21.2 million). In addition to funding, other factors that potentially limit ability to control invasives include the amount of available native seed sources, the time it takes to restore sagebrush to an area once it is removed from a site, and the existence treatments that are known to be effective in the long-term. Monitoring is limited in many cases, and some of the methods are new enough that we are not sure what the population response of sage-grouse will be to these treatments.

Habitat—Energy Development

Research examining the effects of energy development on the greater sage-grouse indicates that greater sage-grouse populations are negatively affected by energy development activities, especially those that degrade important sagebrush habitat, even when mitigative measures are implemented (Braun 1998, Lyon 2000, Naugle et al. 2006). Impacts can result from direct habitat loss, fragmentation of sagebrush via roads, pipelines and powerlines (Kaiser 2006; Holloran et al. 2007), noise (Holloran 2005), and direct human disturbance. The fidelity of sage-grouse to seasonal habitats may exacerbate the effect of energy development, since birds may return to areas disturbed by energy development, but they may no longer reproduce (Lyon and Anderson 2003). The effects of renewable energy development are likely similar as the same types of infrastructure are required. Greater sage-grouse populations can repopulate areas developed for resource extraction after habitat reclamation for the species (Braun 1987). However, there is no evidence that populations attain their previous levels and re-establishment of sage-grouse in a reclaimed area may take 20 to 30 years, or longer (Braun 1998). In developing our 2005 finding, energy development was identified as the most significant extinction risk to the greater sage-grouse in the eastern portion of its range (Colorado, Wyoming and Montana – Management Zones I and II), with the primary concern being the rapidity of development and the persistent demand for petroleum products.

Nonrenewable Energy Development (Oil and Gas): Non-renewable energy development (e.g., petroleum products, coal) has been occurring in sage-grouse habitats since the late 1800s (Connelly et al. 2004, p. 7-28). Interest in developing oil and gas resources in North America has been cyclic based on demand and market conditions (Braun et al. 2002, p. 2). Recently, the exploration and development of fossil fuels in sagebrush habitats has increased as prices and demand are spurred by geopolitical uncertainties and legislative mandates (National Petroleum Council 2007, p. 5-7; EPCA 2000, 42 USC 6201 et seq.; EPCA 2005, 42 USC 15801 et seq.).

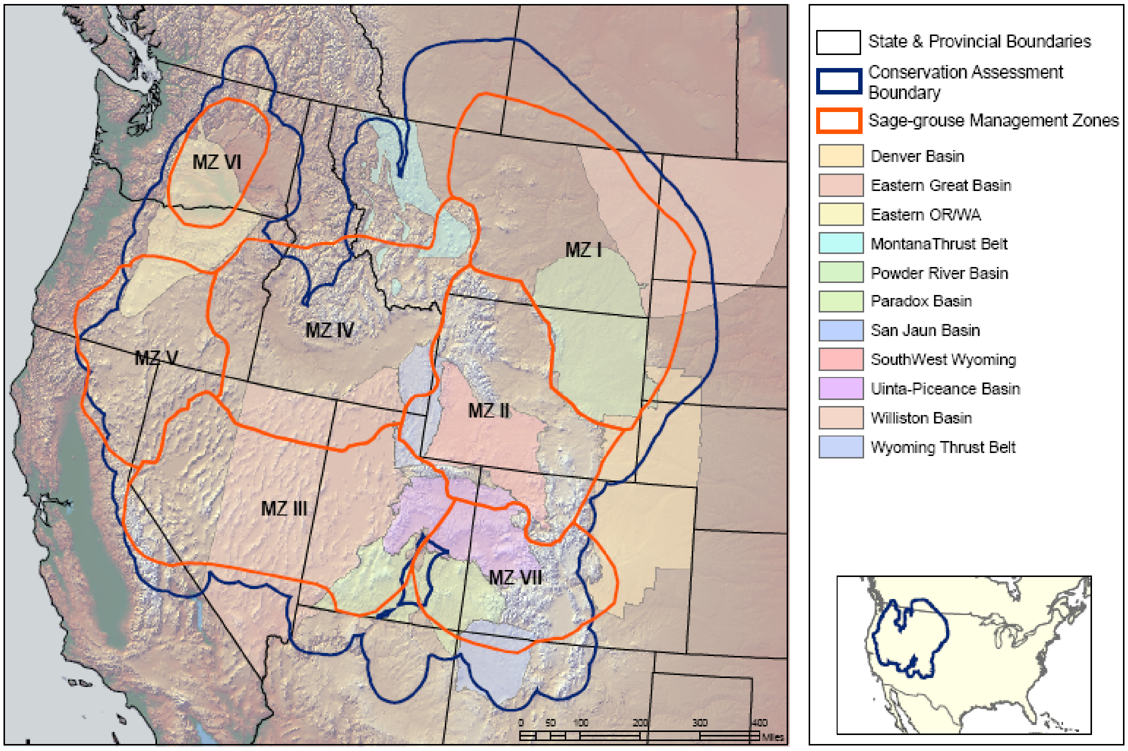
Legislative mandates include those of the Energy Policy and Conservation Act (EPCA) of 1975 (42 USC 6201 et seq) to secure energy supplies and increase the availability of fossil fuels. Re-authorization and amendment of EPCA occurred in 2000 (PL 106-469 section 604) and 2005 (PL 109-58 section 364), mandating inventory of Federal nonrenewable resources, economic incentives for energy development, identification of impediments to timely granting of leases and post-leasing development, and increased development of renewable energy resources (e.g., wind power). In addition, the 2005 Energy Policy Act section 368 mandated designation of federal lands for energy transport corridors (DOE 2008, http://www.oe.energy.gov/epa_sec368.htm, accessed October 14, 2008).

Legislation and energy demand is increasing the pressure to develop conventional sources coincidental to sage-grouse habitats. Moderation of the decline of conventional oil and gas in the future is expected to include mining and processing of clean coal, biomass, unconventional oil and gas, and renewable sources – all of which are existing or potentially available in current sage-grouse habitats (National Petroleum Council 2007, page 6; BLM 2005a, p. 2-4; NREL 2004 in litt; Idaho National Engineering and Environmental Laboratory 2008 in litt.).

Present and future exploration and development is highly likely to focus in areas of highest potential return. Pursuant to the EPCA mandates the Bureau of Land Management, as lead Federal agency for EPCA implementation, released results in 2003 of the first of a 4-phase survey intended to identify onshore oil and gas resources. Phases II and III were published in 2006 and 2008, respectively. Phase III supersedes the previous phases (DOI et al. 2008, p. 6). To date, the EPCA surveys reported the location and relative abundance of oil and gas inventories in 18 geological provinces. These inventories provide information to guide future exploration and to be used as a planning tool for Federal land managers that have areas of high oil and natural gas potential under their jurisdiction.

Available EPCA inventories detail energy resources in 11 geological basins in the greater sage-grouse range identified in the 2006 Conservation Strategy (Stiver et al. 2006, p. 1-11) (Figure 4). Extensive oil and gas reserves are identified in the Williston Basin of North Dakota, South Dakota and Montana; Montana Thrust Belt in Montana; Powder River Basin of Wyoming and Montana; Wyoming Thrust Belt of Wyoming, Utah and Idaho; Southwestern Wyoming Basin including portions of Wyoming, Utah and Colorado; Uinta-Piceance Basin of Colorado and Utah; Eastern Great Basin in Nevada, Utah and Southern Idaho; and Paradox Basin in Utah (Figures 5 and 6). Although all these basins have some component of sage habitats, Wyoming Basins of southern Montana, Wyoming, northwest Colorado and northeast Utah are high in sage-brush dominated landscapes (Knick et al. 2003, p. 613). These areas comprise Management Zones I and II as described in Stiver et al. 2006 (p. 1-11).

Figure 4: EPCA III Energy Basins within the Conservation Assessment Boundary (greater sage-grouse range plus a buffer, as defined by Connelly et al., 2004).



Oil and gas development has occurred in the past, with historic well locations concentrated in Management Zones I, II, III, and VII of eastern Montana, Wyoming, western Colorado and eastern Utah (IHS Incorporated 2006). Currently, greater sage-grouse are most affected by a concentration of development for energy resources in three geological basins – Powder River, Southwest Wyoming, and the Uinta-Piceance. The Powder River Basin is home to an important regional population of the larger Wyoming Basin population, which represents 25 percent of the sage-grouse in the species range (Connelly et al. 2004, p. A4-37). The Powder River Basin serves as a link to fringe populations in eastern Wyoming and western South Dakota and between the Wyoming Basin and central Montana. The Pinedale Anticline Project Area is in the Southwestern Wyoming Basin. The subpopulation in southwest Wyoming and northwest Colorado is a stronghold for sage-grouse with some of the highest estimated densities of males per km^2 anywhere in the remaining range of the species (Connelly et al. 2004, pp. 6-62, A5-23). The Southwest Wyoming/Northwest Colorado subpopulation of the Piceance Basin has historically supported over 800 leks (Connelly et al. 2004, p. 6-62).

Figure 5: EPCA III Total Oil Density within the Conservation Assessment Boundary **(**greater sage-grouse range plus a buffer, as defined by Connelly et al., 2004).

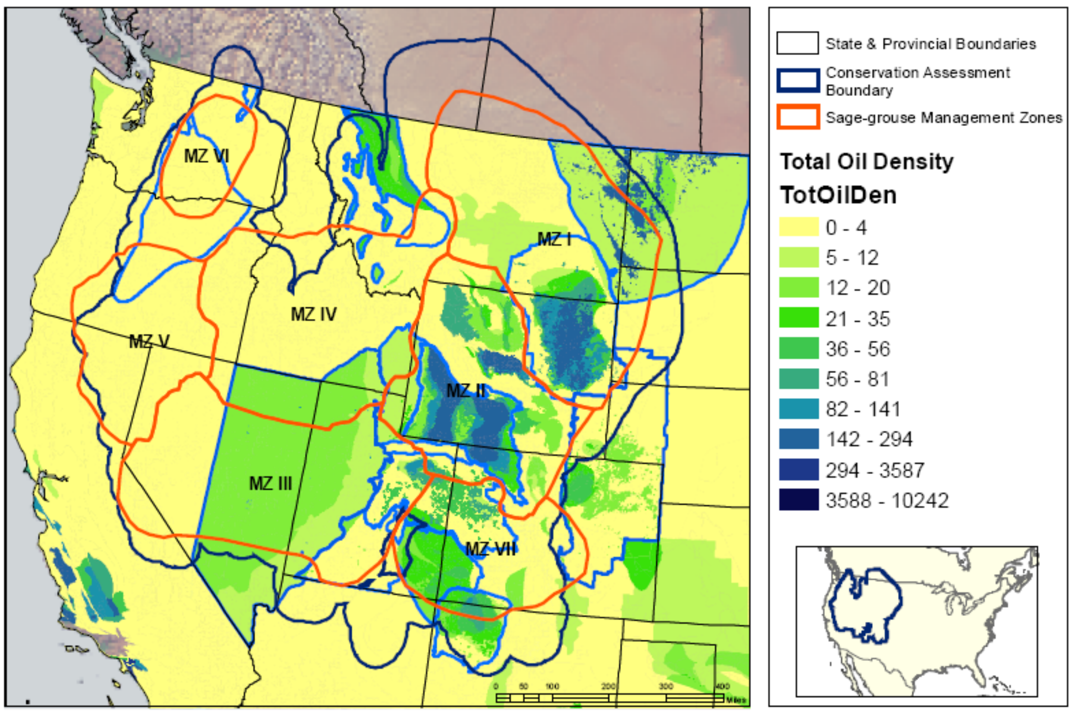
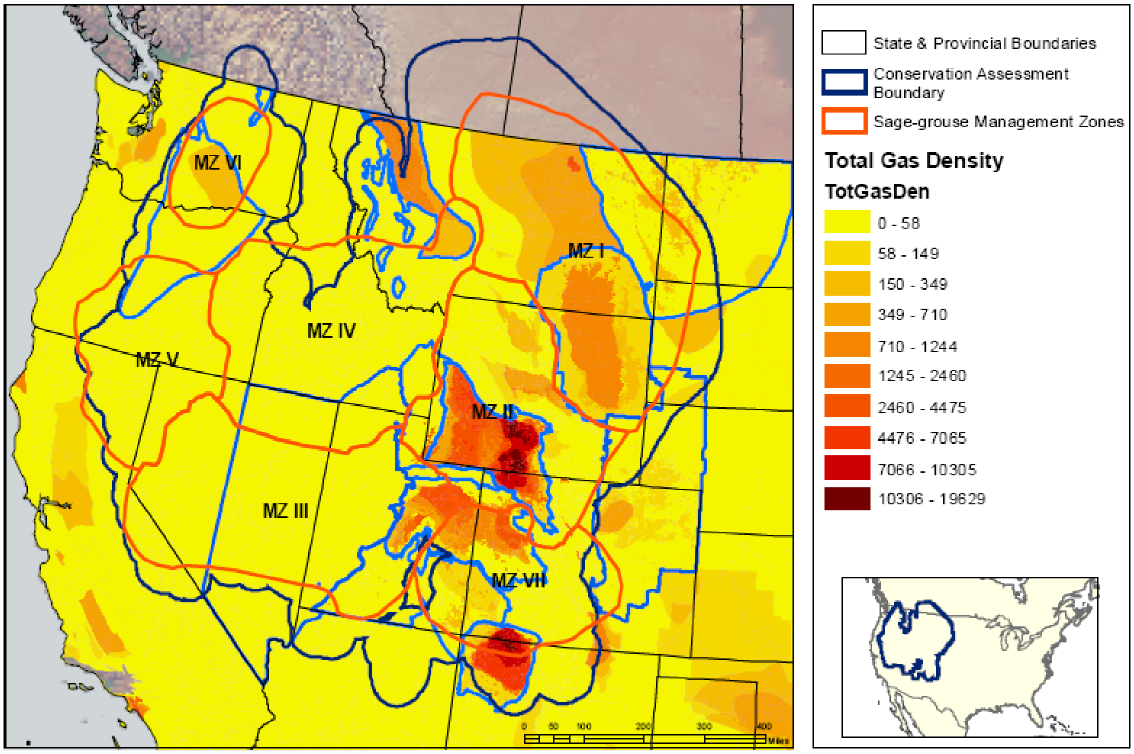


Figure 6: EPCA III Total Gas Density within the Conservation Assessment Boundary (greater sage-grouse range plus a buffer, as defined by Connelly et al., 2004).



Coal-bed natural gas extraction is the most recent development in the Powder River Basin (Management Zone I). In 2002, the BLM proposed development of 39,367 coal-bed methane wells and 3,200 conventional oil or gas wells in addition to an existing 12,024 coal-bed methane wells drilled or permitted (BLM 2002, p. 2-3). Wells would be developed and in place over a ten-year period. The BLM estimated 202,808 surface acres (820 km^2) of disturbance from all activities such as well pads, pipelines, roads, compressor stations and water handling facilities over a 32,400-km^2 (8 million ac) area (BLM 2002, p. 2). Roads and water handling facilities were expected to be long-term disturbances encompassing approximately 383 km^2 (95,140 ac) (p. 3). By the end of 2007, approximately 35,000 producing wells were in place on federal, state, and private holdings covering 24,000 km^2 (5,9000,000 ac) (Naugle 2008, in review, p. 30). The

Powder River Basin is also the largest actively-producing coal basin in the U.S. ((MOGC 2008, http://www.montanacoalcouncil.com/facts_figures.html, accessed October 19, 2008).

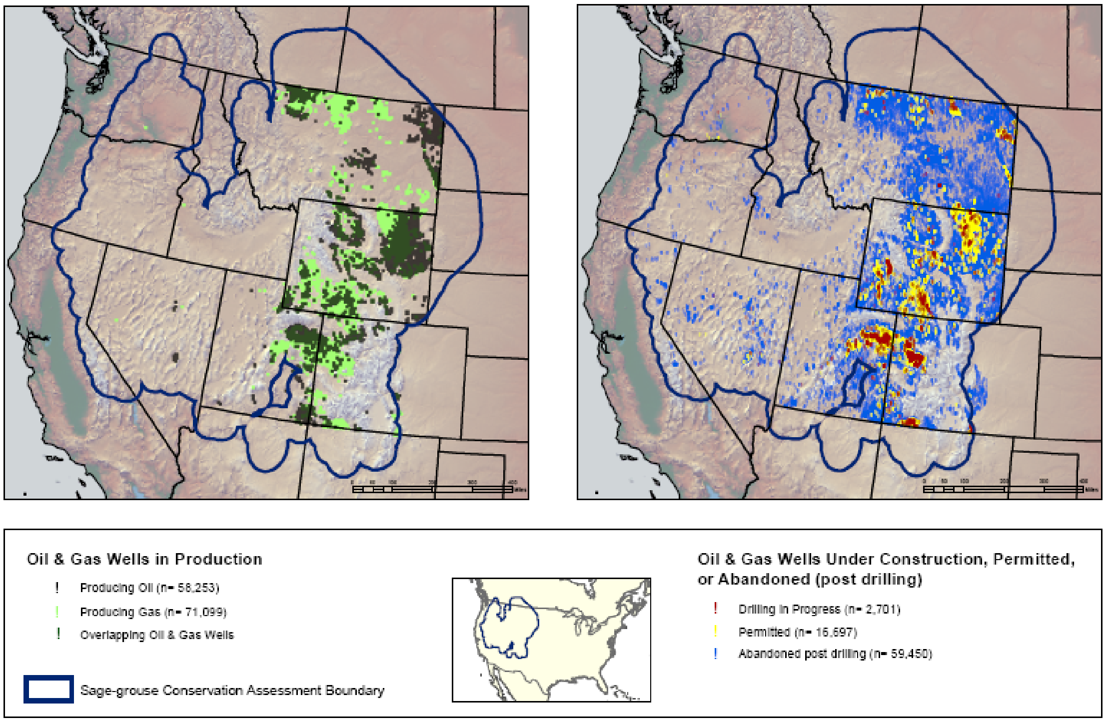
The BLM published the Record of Decision (ROD) in 2000 for Pinedale Anticline Project Area in southwest Wyoming (Management Zone II) (BLM 2000). The project description included up to 900 drill pads, including dry holes, over a 10 to 15-year development period (BLM 2008, p. 4-4). By the end of 2005, approximately 457 wells on 322 well pads were under production (p. 6). In 2008, the BLM amended the project to accommodate an accelerated rate of development exceeding that in the 2002 project description (BLM 2008, p. 4). Approximately 250 new well pads are proposed in addition to pipelines and other facilities (p. 36). Total initial direct disturbance acres for the entire Pinedale project are approximately 10,400 ha (25,800 ac) with over 7,200 ha (18,000 ac) in sagebrush land cover type (p. 4-52).

The Jonah Gas Project is also underway in the Pinedale Anticline area of the Southwest Wyoming Basin. In 2006, the BLM issued a ROD and EIS to extend the existing project to an additional 3,100 wells and up to 6,556 ha (16,200 ac) of new surface disturbance (BLM 2006, p. 2-4). In addition, at least 64 well pads would be situated per 259 km^2 (640 ac), and up to 761 km (473 mi) of pipeline and roads, 56 ha (140 ac) of additional disturbance for ancillary facilities (p. 2-5) would occur. We did not calculate the area disturbed by oil and gas development in the Jonah Gas Project as of 2008.

The Pinedale Anticline and Jonah Gas Field Projects as analyzed by the BLM EIS's are not the only oil and gas development occurring in Wyoming. According to the Wyoming Oil and Gas Commission completed wells in Wyoming counties with sage habitats increased from a total of 37,144 in 2005 to 42,510 in 2007. An additional 6,209 applications for permit to drill (APD) were approved from January through September 2008 in these counties (WOGC 2008, http://wogcc.state.wy.us, accessed September 29, 2008).

In 2006, there were approximately 129,000 actively producing oil and gas wells (IHS Incorporated 2006) within the sage-grouse range area identified in the Greater Sage-grouse Comprehensive Conservation Assessment and Strategy (Connelly et al. 2004, p. 1-16; Stiver et al. 2006, p. 1-9) (Figure 7). Development activity has been focused, as stated above, in northeast Wyoming, southwest Wyoming, northwest Colorado, and northeast Utah.

Figure 7: Oil and Gas Well Sites within the Sage-grouse Conservation Assessment Boundary. (Greater sage-grouse range plus a buffer, as defined by Connelly et al., 2004).



Data Source: IHS Incorporated; Date data published: Oct 30, 2006. No well site data were available for North Dakota or South Dakota.

Figure 7 is based on the IHS 2006 dataset that is the most recent comprehensive information on well siting available to us. The number of oil and gas wells since 2006 is provided for perspective on the increasing fossil fuel extraction demands in the greater sage-grouse range. However, the 2007 to 2008 well information may be based on administrative boundaries and not necessarily reflect a precise relationship with sage-grouse habitat. We note where newer well data is specific to known sage-grouse habitats.

Since our last review of the species status in 2005, oil and gas wells increased in the Uinta-Piceance Basin in occupied sage-grouse habitats of northwestern Colorado and northeastern Utah by 325 and 870 wells, respectively (FWS 2008a in litt.). There is an estimated 9,200 units operating in counties of northwest Colorado, an increase of over

2,000 producing wells since 2005 (COGCC 2008, http://cogcc.state.co, accessed September 30, 2008). Permits for drilling in Montana totaled 1,474 in sage-grouse habitat since 2005 (FWS 2008 in litt.). Seventy-three of the Montana wells were subsequently cancelled or abandoned, while over 1,400 are actively producing (MBOG 2008, http://bogc.dnrc.mt.gov/onlinedata.asp, accessed September 30, 2008).

Prior to 2005, few studies were available specifically reporting on the effects of oil and gas development on sage-grouse. While each of the available studies reported sage-grouse population declines, specific causes for the negative impacts were not determined. Studies conducted in Alberta, Canada; Powder River Basin Wyoming; and Jackson County, Colorado reported direct habitat losses, higher human activity and effects of powerlines associated with energy development. Lek abandonment and decreased lek attendance were noted in all three locations. In Canada, the development of well pads and associated roads in the 1980's resulted in the abandonment of three lek complexes, and a fourth complex was reduced to a single lek. The abandoned lek complexes were within 200 m (220 yd) of development features. Two leks abandoned after direct disturbance remained inactive for at least 10 years (Braun et al. 2002, p. 5). Subsequent to development of the Manyberries Oil Field in Alberta, male sage-grouse counts fell to the lowest known level.

The development of oil reserves in Jackson County, Colorado was concurrent with decline of sage-grouse numbers in the oil field area (Braun 1998, pp. 5-6). Sage-grouse have persisted in at least one long-term development area despite declining numbers, possibly due to lek locations out of the line-of-sight of an active well or powerline (Braun et al. 2002, p. 7).

Fewer males attended leks within 0.4 km (0.25 mi) of a well compared to undisturbed leks in the Powder River Basin, Wyoming. Recruitment of males on the affected leks was lower than undisturbed leks where recruitment actually increased (Braun et al 2002, p. 10; BLM 2003, p. 4-267). Lek recruitment was lower within 0.4 km (0.25 mi) of powerlines, possibly due to raptor predation. Grouse numbers were lower on leks within 1.6 km (1 mi) of compressor stations (Braun et al. 2002, p.11).

Based on nest initiation and habitat fidelity results, Lyon and Anderson (2003, p. 5) concluded that impacts occur greater than 0.4 km (0.25 mi) from well pads. Hens that have successfully nested will return to the same area to nest every year. If these habitats are affected by oil and gas development, there is strong potential that previously successful hens will return but not initiate nests (Lyon 2000, p. 109).

Our understanding of the effects of energy development on sage-grouse has increased since 2005. Six scientific studies are available that report specifically on the impacts of oil and gas development to sage-grouse in geographic areas experiencing high levels of development. Three investigations are published in peer-reviewed journals (Doherty et al. 2008, Walker et al. 2007, Aldridge and Boyce 2007), one is a U.S. Geological Survey report (Holloran et al. 2007), and two are graduate-level academic works (Kaiser 2006, Holloran 2005). All reported negative impacts of oil and gas development to sage-grouse. Additional non-published reports are available as well (Clark et al. 2008, Taylor et al. 2007).

Walker et al. (2007) analyzed trends in male attendance at leks in coal-bed natural gas fields in the Powder River Basin in northeast Wyoming and southeast Montana. Male lek attendance inside gas fields declined by 82 percent over a 4-year period while males at leks outside development declined slightly then rebounded over the same period. A higher proportion of leks disappeared in gas fields, and disappearance averaged 4.1 ± 0.9 years from the start of development. Lek persistence was strongly influenced by the proportion of sagebrush within 6.4 km (4 mi) of the lek. After controlling for habitat, development negatively affects lek attendance when disturbance occurs within 0.8 km (0.5 mi) and 3.2 km (2 mi) of the lek. The BLM standard leasing stipulations to minimize impacts to sage-grouse include no surface disturbance requirements within 0.25 mi (0.4 km) and timing restrictions for drilling operations. The authors state that the current lease stipulations are inadequate to ensure lek persistence and breeding populations over a larger area.

In the Manyberries Oil Field in southern Alberta, the investigators' objective was to identify nesting and brood-rearing habitat necessary for persistence on a landscape scale. Female sage-grouse selected sites for nesting and brooding in areas with moderate sagebrush cover in a patchy configuration and strongly selected against sites associated with anthropogenic edge habitat (Aldridge and Boyce 2007). Poor nest success and chick survival are attributed to a lack of suitable nesting and brooding habitat as a consequence of cumulative human development. Succulent forbs around individual oil wells attracted broods that might otherwise avoid risky environments associated with human activity. These areas acted as sink habitat in a landscape limited in supporting capacity.

Doherty et al. (2008) investigated female sage-grouse use of wintering habitat in the Powder River Basin of northeast Wyoming and southeast Montana. Percent sagebrush was highly predictive of female use. Sage-grouse were more likely to occupy sagebrush habitat lacking wells within a 4-km^2 (988 ac) area compared to areas with 12.3 wells per 4 km^2 (1 well/80 ac), the maximum well density permitted on federal lands.

Holloran (2005) assessed the responses of breeding populations to energy development, habitat selection, survival or lek tenacity of males, and selection of nesting and early brooding habitats by females in the Pinedale Anticline Project Area and Jonah II Gas Field in southwest Wyoming. The investigation showed male lek attendance decreased with distance to the nearest rig, producing well, or main haul road. Declines were most severe within 5 km (3 mi) of an active drilling rig and 3 km (1.9 mi) of a producing gas well or main haul road. Leks downwind of a drilling rig showed the highest rate of decline, and the author suggested that drilling noise was a contributing factor. The rate of decline of male lek attendance was greatest where leks were centrally located in the development field. Male attendance decreased over 23 percent where well density was 5 or more within 3 km (1.9 mi) (1 well/283 ha or 1 well/700 ac). Leks that became inactive during the study did so within 3-4 years of development. Adult females showed nest site fidelity in consecutive years regardless of the level of development, but yearling females showed avoidance by nesting farther from disturbance than would be expected based on available habitat. The relationship between nest success and development was inconclusive. The author concluded that decreased survival and avoidance of energy development contributed to lek extirpation.

Kaiser's (2006) investigation in the Pinedale Anticline area of southwest Wyoming indicated that development causes decreasing male attendance at leks, and the decrease in attendance is exacerbated relative to distance. Lek loss was more likely near the center of development and based on lower recruitment of males and displacement of yearling males to areas less impacted. Similar displacement of yearling females was inconclusive based on small sample size.

Holloran et al (2007) assessed the affect of gas development on yearling sage-grouse in the Pinedale Anticline area of southwest Wyoming. Reduced demographic metrics and avoidance of infrastructure contributed to population decline within natural gas fields. Both male and female yearlings avoided the infrastructure of natural gas fields when establishing breeding territories or selecting nest location. Yearlings had lower annual survival rates. Developments affect loss of leks and a functional loss of nesting habitat within 930 m (~0.6 mi) of infrastructure.

Additional unpublished investigations and reports recount the interaction of sage-grouse in proximity to oil and gas developments. Naugle et al. (2006) characterized winter habitat selection in the Powder River Basin of Wyoming and Montana as part of a larger study of sage-grouse and coal-bed natural gas (CBNG) recovery – see Doherty et al. 2008.

In Wyoming, Clark et al. (2008) examined the association between lek occupancy and energy development, habitat quality, and density of adjacent leks at five spatial scales. The potential for lek abandonment increased in proximity to energy development (within 3.2 km or 2 mi) with the magnitude varying by site and year (p. 14, 16). Colonization of unoccupied leks was positively associated with lek density within 0.4 km (0.25 mi) (p. 16). The authors suggested that retaining suitable sagebrush habitat surrounding lek complexes be a conservation priority (p. 23). They further concluded that a rangewide conservation management strategy may not be appropriate at smaller scales. Local sage-grouse habitat and population conditions should be considered when developing constraints on human activity relative to energy development (p. 25-26).

Taylor et al. (2007) reviewed lek data relative to well density in six oil and gas development areas in Wyoming. Unfortunately, limitations associated with study design and sample selection preclude us from using their results in our analyses.

Using 2006 well-site locations, we estimated that sagebrush habitats cover over 292,000 km^2 (72 million ac), including approximately 162,000 km^2 (40 million ac) of known sage-grouse breeding habitat, in Management Zones I and II of Montana, Wyoming, northwest Colorado, and northeast Utah. Breeding habitat is defined as a 6.4-km (4-mi) radius around known lek points and includes the range of the average distances between nests and nearest lek (Autenrieth 1981, p. 18; Wakkinen et al. 1992, p. 2). Within these 162,000 km^2, approximately 16,000 km^2 (4 million ac) are within 0.4 km (0.25 mi) of a producing well, drilling operation or site with an approved APD (FWS in litt 2008b), the distance buffer intended by stipulation and management guidelines to minimize impacts to sage-grouse. Conservatively, the impacts to breeding populations extend beyond the current 0.4-km buffer distance up to 3.2 km (2 mi) based on current research (Walker et al. 2007, p. 2651). Depending on local habitat conditions, configuration and density of wells, sage-grouse could be impacted by existing oil and gas development on closer to 48,000 km^2 (16 million acres) or 22 percent of the sagebrush habitat (FWS in litt. 2008b). This calculation does not take in to account the added effects of loss of habitat or habitat effectiveness resulting from other anthropogenic factors occurring in concert with energy development such as tillage, urban expansion, or predation.

The development of oil and gas resources requires surveys for economically recoverable reserves, construction of well pads and access roads, subsequent drilling and extraction, and transport of oil and gas, typically through pipelines. Ancillary facilities can include compressor stations, pumping stations, electrical generators and powerlines (Connelly et al. 2004, p. 7-39; BLM 2007b, page 2-110). Surveys for recoverable resources occur primarily through seismic activities, using vibroesis buggies (thumpers) or shothole explosives. Well pads vary in size from 0.10 ha (0.25 ac) for coalbed natural gas wells in areas of level topography to greater than 7 ha (17.3 ac) for deep gas wells and multiwell pads (Connelly et al. 2004, p. 7-39; BLM 2007b, page 2-123). Pads for compressor stations require 5 to 7 ha (12.4 to 17.3 ac) (Connelly et al. 2004, p. 7-39). Well densities and spacing are typically designed to maximize recovery of the resource and are administered by State oil and gas agencies and the BLM (Connelly et al. 2004 p. 7-39, 7-40). Based on a review of project EIS's, Connelly et al. (2004, p. 7-41) concluded that the economic life of a coalbed methane well averages 12 to 18 years and 20 to 100 years for deep oil and gas wells.

Energy development impacts sage-grouse and sagebrush habitats through direct habitat loss from well pad, access construction, seismic surveys, roads, powerlines and pipeline corridors; indirectly from noise, gaseous emissions, changes in water availability and quality, and human presence; the interaction and intensity of effects could cumulatively or individually lead to fragmentation (Suter 1978, pp. 6-13; Aldridge 1998 p. 12; Braun 1998, pp. 6-10; Aldridge and Brigham 2003, p. 31; Knick et al. 2003, p. 612, p. 619; Lyon and Anderson 2003, pp. 489-490; Connelly et al. 2004, pp. 7-40, 7-41; Holloran 2005, pp. 56-57; Holloran 2007, pp. 18-19; Walker et al. 2007, pp. 2652-2653; Aldridge and Boyce 2007, pp. 521-522; Doherty et al. 2008, p. 193; Zou et al. 2006, pp. 1039-1040).

Air quality could be affected where combustion engine emissions, fugitive dust from road use and wind erosion, natural gas-flaring, fugitive emissions from production site equipment, and other activities (BLM 2008, p. 4-74) occur in sage-grouse habitats. Presumably, as with surface mining, these emissions are quickly dispersed in the windy, open conditions of sagebrush habitats (Moore and Mills 1977, p. 109), minimizing the potential effects on sage-grouse. However, high density development could produce airborne pollutants that reach or exceed quality standards in localized areas for short periods of time (BLM 2008, p. 4-82 to 4-88). Walker (in litt. 2008) characterized emissions from well flaring in the Pinedale Anticline area of Sublette County, Wyoming. The investigator suggested a comprehensive study be conducted by regulatory agencies of the potential health effects of alkali elements in combusted well-plume material. No information is available regarding the effects to sage-grouse of gaseous emissions produced by oil and gas development.

Direct habitat loss from the human footprint has contributed to decreased population numbers and distribution of the greater sage-grouse (Connelly et al. 2004, p. 7-40). The footprint of energy development contributes to direct habitat loss from construction of well pads, roads, pipelines, powerlines, and potentially through the crushing of vegetation during seismic surveys. The amount of direct habitat loss within an area will ultimately be determined by well densities and the associated loss from ancillary facilities. For example, over 54,000 wells have been authorized for coal-bed methane development on public land or mineral estate in a 24,000 km^2 (5,930,000 ac) area in the Powder River Basin of Wyoming and Montana (BLM 2002, p. 2). Since 2001, typically wells have been spaced at 32 ha (80 ac) intervals or 8 wells per section. The combined footprint of infrastructure is relatively small at 6-8 ha (15-20 ac) per 2.5 km^2 (section) (Braun et al. 2002, p. 9). Approximately 35,000 wells were completed by the end of 2007 corresponding to a direct habitat loss of an estimated 354 km^2 (87,500 ac) (Naugle 2008, p. 30, in review; FWS 2005, p. 83). An additional 333 km^2 (82,400 ac) will be directly affected by well installation by 2011 (BLM 2003, p. 2-73).

In 2004, Connelly et al. estimated that habitat loss from all existing natural gas pipelines in the conservation assessment area was a minimum of 4,740 km^2 (1,852 mi^2, 1.17 million ac, 474,000 ha; less than 1 percent of their assessment area). Currently, no figures are available to update the 2004 estimate. The current habitat loss from pipeline right-of-ways is therefore surmised to be proportional to the increase in completed wells since 2005. Short-term disturbances such as pipeline construction are often concurrent with project development, but habitats would not be restored to pre-disturbance conditions for an extended period (BLM 2003, p. 4-158).

Negative effects of direct habitat disturbance can be offset by successful reclamation. Reclamation of areas disturbed by oil and gas development can be concurrent with field development or conducted after the shut-in or abandonment of the well or field. Sage-grouse may repopulate the area as disturbed areas are reclaimed. However, there is no evidence that populations will attain their previous size, and reestablishment may take 20 to 30 years (Braun 1998, p. 144). For most developments, return to pre-disturbance population levels is not expected due to a net loss and fragmentation of habitat (Braun et al. 2002, p. 150). After 20 years, sage-grouse have not recovered to pre-development numbers in Alberta, even though well pads in these areas have been reclaimed (Braun et al. 2002, pp. 4-5). In some reclaimed areas, sage-grouse have not returned (Aldridge and Brigham 2003, p. 31).

Habitat fragmentation, resulting from oil and gas development infrastructure including access roads, may have effects on sage-grouse greater than the associated direct habitat losses. The Powder River Basin infrastructure footprint is relatively small (typically 6-8 ha/2.6 km^2 (15-20 ac/section). Considering the mostly contiguous nature of the project area, the density of facilities could affect sage-grouse habitats over the entire project area up to 24,000 km^2 (5,930,000 ac).

Roads associated with oil and gas development were suggested to be the primary impact to greater sage-grouse due to their persistence and continued use even after drilling and production ceased (Lyon and Anderson 2003, p. 489). Declines in male lek attendance were reported within 3 km (1.9 mi) of a well or haul road with a traffic volume exceeding 1 vehicle per day (Holloran 2005, p. 40). Sage-grouse may also be at increased risk for collision with vehicles simply due to the increased traffic associated with oil and gas activities (BLM 2003, p. 4-222; Aldridge 1998, p. 14).

Noise can drive away wildlife, cause physiological stress and interfere with auditory cues and intraspecific communication. Aldridge and Brigham (2003, p.32) reported that, in the absence of stipulations to minimize the effects, mechanical activities at well sites may disrupt sage-grouse breeding and nesting activities. Hens bred on leks within 3 km (1.9 miles) of oil and gas development in the upper Green River Basin of Wyoming selected nest sites with higher total shrub canopy cover and average live sagebrush height than hens nesting away from disturbance (Lyon 2000, p. 109). The author hypothesized that exposure to road noise associated with oil and gas drilling may have been one cause for the difference in habitat selection. However, noise could not be separated from the potential effects of increased predation resulting from the presence of a new road. In the Pinedale Anticline area of southwest Wyoming, lek attendance declined most noticeably downwind from a drilling rig indicating that noise likely affected male presence (Holloran 2005, p. 49).

Above-ground noise is typically not regulated to mitigate effects to sage-grouse or other wildlife (Connelly et al. 2004, p. 7-40). Ground shock from seismic activities may affect sage-grouse if it occurs during the lekking or nesting seasons (Moore and Mills 1977, p. 137). We are unaware of any research on the impact of ground shock to sage-grouse.

Water quality and quantity may be affected in oil and gas development areas. The impacts are similar relative to the contamination of water supplies by toxic elements and pathogens with the addition of potential oil contamination in settling or condensate ponds. In many large field developments, the contamination threat is minimized by storing water produced by the gas dehydration process in tanks. Water may also be depleted from natural sources for drilling or dust suppression purposes. Concentrating wildlife and domestic livestock may increase habitat degradation at remaining water sources. Negative effects of changes in water quality, availability and distribution are a reduction in habitat quality (e.g., trampling of vegetation, changes in water filtration rates), habitat degradation (e.g., poor vegetation growth), which could result in brood habitat loss. However, we have no data to suggest this, by itself, is a limiting factor to sage-grouse.

Water produced by coal-bed methane drilling may benefit sage-grouse through expansion of existing riparian areas and creation of new areas (BLM 2003, p. 4-223). These habitats could provide additional brood rearing and summering habitats for sage-grouse. However, the increased surface-water on the landscape may negatively impact sage-grouse populations by providing an environment for disease vectors. Based on the 2003 discovery of West Nile virus in the Powder River Basin, and the resulting mortalities of sage-grouse (Naugle et al. 2004, page 705), there is concern that produced water could be a negative impact if it creates suitable breeding reservoirs for the mosquito vector of this disease (see also discussion on Natural Enemies below). Produced water could also result in direct habitat loss through prolonged flooding of sagebrush areas, or if the discharged water is of poor quality because of high salt or other mineral content, either of which could result in the loss of sagebrush and/or grasses and forbs necessary for foraging broods (BLM 2003, p. 4-223).

Increased human presence resulting from oil and gas development can also impact sage-grouse either through avoidance of suitable habitat, disruption of breeding activities, or increased hunting and poaching pressure (Aldridge and Boyce, 2007 p. 518); Aldridge and Brigham 2003, pp. 30-31; Braun et al. 2002, pp. 4-5; BLM 2003a; Doherty et al. 2008, p. 194). Sage-grouse may also be at increased risk for collision with vehicles simply due to the increased traffic associated with oil and gas activities (BLM 2003, p. 4-216).

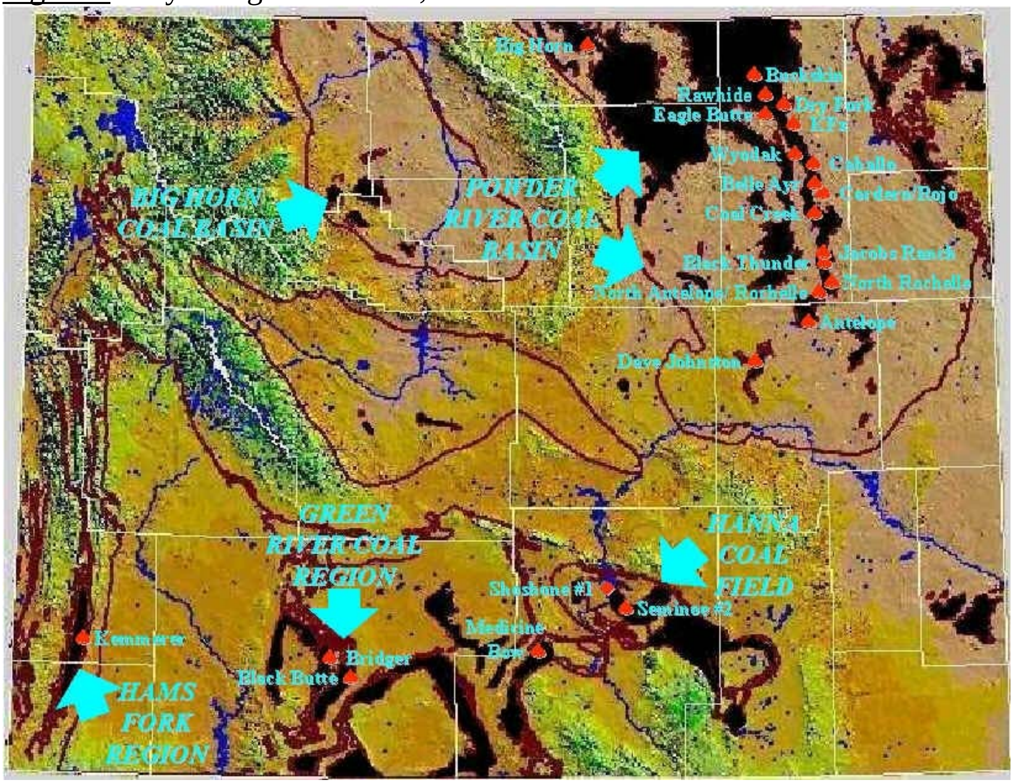
Nonrenewable Energy Development (Mining): Mining began in the range of the sage-grouse before 1900 (U.S. Census 1913, p. 187, State of Wyoming in litt 1898) and continues today. Currently, surface and subsurface mining activities for numerous resources are conducted in all the 11 states across the sage-grouse range. We do not have comprehensive information on the number or surface extent of mines across the range, but we do know that the development of mineral resources is occurring on a large-scale and important to the economies of a few of the states. For example: Nevada (Management Zones III, IV, and V) ranked second in the U.S. in terms of value of overall nonfuel mineral production in 2006 (U.S. Geological Survey, p.10); Wyoming (Management Zone I and II) is the largest coal producer in the U.S., and the top ten producing mines in the country are located in Wyoming's Powder River Basin (Management Zone I) (Wyoming Mining Association 2008, p. 2).

Since 2005, we have received information that Idaho's Smoky Canyon Phosphate Mine (Management Zone IV) expanded to disturb 12 ha (30 ac) of sage-grouse habitat. A preliminary estimate of 1,095 ha (2,707 ac) of sage-grouse habitat will be directly impacted by mining activities, currently in the planning phase, in Montana, (Management Zone I), Idaho (Management Zone IV), Nevada (Management Zone IV), Utah (Management Zone III) and Oregon (Management Zone V) (FWS in litt. 2008a).

Nonrenewable Energy Development (Coal Mining): Between 2006 and 2007, surface coal production decreased 9 percent in Colorado while increasing by 1.6 to 4.4 percent in Wyoming (Management Zone I) and Montana (Management Zone I), respectively (EIA, http://www.eia.doe.gov/cneaf/coal/page/acr/table1.pdf, accessed October 19, 2008). The number of Wyoming coal mines increased from 19 in 2005 to 23 in 2008 (Wyoming Mining Association 2005, p 5; Figure 8 from the Wyoming Mining Association, http://www.wma-minelife.com/coal/coalfrm/coalfrm1.htm, accessed October 19, 2008). Most, if not all, of Wyoming's 23 coal mines are in sagebrush and in the sage-grouse distribution area. Sixteen of these mines are located in the Powder River Basin of Management Zone I where oil and gas development is extensive and described previously in this document.

Coal mining in Montana is also focused in the Powder River Basin just north of the Wyoming border. In Wyoming and Montana, an estimated 55,800 ha (138,000 ac) have been disturbed by coal mines and associated facilities; disturbance increased approximately 17,000 ha (42,000 ac) between 2005 and 2007 (FWS 2005, p. 75; FWS in litt. 2008a; Wyoming Mining Association 2008, p. 7). Wyoming estimates that 27,500 ha (68,000 ac) of mine-disturbed land has been reclaimed (Wyoming Mining Association 2008, p. 7), but we have no knowledge of the effectiveness of these reclamations in providing functional sage-grouse habitat.

Figure 8: Wyoming Coal Mines, 2008



Surface and subsurface mining for mineral resources (coal, uranium, copper, aggregate and others) results in direct loss of habitat if occurring in sagebrush habitats. The direct impact from surface mining is usually greater than subsurface activity. Habitat loss from both types of mining can be exacerbated by the storage of overburden in otherwise undisturbed habitat. If the construction of mining infrastructure is necessary, additional direct loss of habitat could result from structures, staging areas, roads, railroad track and powerlines. Sage-grouse and nests could be directly affected by trampling or vehicle collision.

Sage-grouse could be impacted indirectly from an increase in human presence, land use practices, ground shock, noise, dust, reduced air quality, degradation of water quality and quantity, and changes in vegetation and topography (Moore and Mills 1977, total; Brown and Clayton 2004, p. 2).

An increase in human presence increases collision risk with vehicles and potentially exposes sage-grouse and other wildlife to pathogens introduced from septic systems and waste disposal (Moore and Mills 1977, pp.114-116, 135). Water contamination could also occur from leaching of waste rock and overburden and nutrients from blasting chemicals and fertilizer (Moore and Mills 1977, p. 115, 133). Altering of water regimes could lead to decreased surface water and eventual habitat degradation from wildlife or livestock concentrating at remaining sources. Sage-grouse do not require free water (Schroeder et al. 1999, p. 6), therefore local water quality deterioration or dewatering is not expected to have population-level impacts. Degradation of riparian areas could result in a loss of brood habitat.

Mining and associated activities creates an opportunity for invasion of exotic and noxious weed species that alter suitability for sage-grouse (Moore and Mills 1977, pp. 125, 129). Reclamation is required by state and federal law, but laws generally allow for a change in post-mining land use. Restoration of sagebrush could take 20 to 30 years before suitability for grouse is achieved (Braun 1998, p. 6).

Heavy equipment operations and use of unpaved roads produces fugitive dust that can interfere with plant photosynthesis and insect populations. Most large surface mines are required to control fugitive dust. Gaseous emissions generated from heavy equipment operation are quickly dispersed in open, windy areas typical of sagebrush (Moore and Mills 1977, p.109).

Blasting, to remove overburden or the target mineral, produces noise and ground shock. The full affect of ground shock on wildlife is unknown. Repeated use of explosives during lekking activity could potentially result in lek or nest abandonment (Moore and Mills 1977, p. 137). Noise from mining activity could mask vocalizations resulting in reduced female attendance and yearling recruitment as seen in sharp-tailed grouse (*Pedioecetes phasianellus*) (Amstrup and Phillips 1977, pp. 23, 25-27). In this study, the authors found that the mining noise in the study area was continuous across days and seasons and did not dissipate as it traveled across the landscape. The mechanism of how noise affects sage-grouse is not known but it is known that sage-grouse depend on acoustical signals to attract females to leks (Gibson and Bradbury 1985, pp. 81-82; Gratson 1993, pp. 693-694).

A few studies specifically examine the effects of coal mining on greater sage-grouse. No new studies have been published since the 2005 finding. The results of previous investigations are summarized here.

In a study in North Park, Colorado, overall sage-grouse population numbers were not reduced, but there was a reduction in the number of males attending leks within 2 km (0.8 mi) of three coal mines, and existing leks failed to recruit yearling males (Braun 1986, pp. 229-230; Remington and Braun 1991, pp. 131-132). New leks formed farther from mining disturbance (Remington and Braun 1991, p. 131). Additionally, some leks that were abandoned adjacent to mine areas were reestablished when mining activities ceased, suggesting disturbance rather than habitat loss was the limiting factor (p.132). There was no decline in hen survival in a population of sage-grouse near large surface coal mines in northeast Wyoming, and nest success appeared not to be affected by adjacent mining activity (Brown and Clayton 2004, p. 1). The authors concluded however that continued mining would result in fragmentation and eventually impact sage-grouse persistence if adequate reclamation was not employed (p.16).

Surface coal mining and associated activities have negative short-term impacts on sage-grouse numbers and habitats near mines (Braun 1998, p. 5). Sage-grouse will reestablish on mined areas once mining has ceased, but there is no evidence that population levels will reach their previous size. Population reestablishment could take 20 to 30 years (Braun 1998, p. 6). Local sage-grouse populations could decline if several leks are affected by coal mining, but the loss of one or two leks in a regional area was likely not limiting to local populations in the Caballo Rojo Mine in northeastern Wyoming based on the presence of viable habitat elsewhere in the region (Hayden-Wing Associates 1983, p. 81).

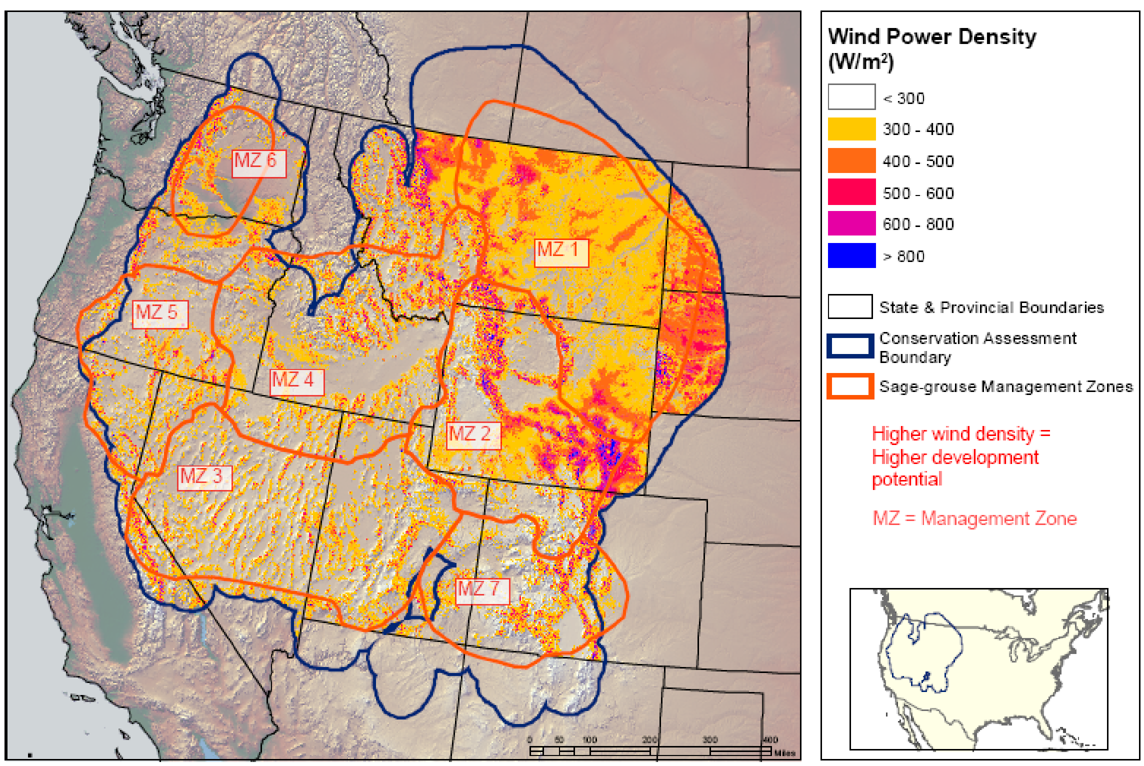
The investigations specific to the effects of mining on sage-grouse reveal that mining directly removes habitat, indirectly interferes with auditory clues important to mate selection, and affects a decrease of males and inhibits yearling recruitment at leks in proximity to mining activity. Sage-grouse habitat reestablishment could take 20 to 30 years, and recovery of population numbers in an area post-disturbance is uncertain. Similar avoidance of disturbance has been noted in recent investigations of oil and gas development in Wyoming and discussed in detail in the Nonrenewable Energy section above. The studies recounted here were conducted on a local scale that provides limited insight into impacts at larger landscape perspective. In Wyoming specifically, the cumulative impacts of surface coal mine disturbance, concurrent increases in oil and gas development, increased development of renewable energy resources (discussed in the following section), and transmission infrastructure development could have significant impacts on sage-grouse in the Powder River Basin. The Powder River Basin is home to an important regional population of the larger Wyoming Basin populations covering most of Wyoming, northwest Colorado and northeast Utah (Connelly et al. 2004, p. 6-62, 6-63).

Renewable Energy Development: The demand for and development of renewable energy resources is increasing. Renewable energy production increased from 6,444 trillion Btu in 2005 to 6,922 trillion Btu in 2006. Production was down slightly in 2007, but is again on the upswing. Year-end energy production by renewables is expected to reach 7,452 trillion Btu based on the first six months of 2008 (EIA in litt. 2008). Wind, geothermal, solar and biomass are renewable energy sources developable in sage-grouse habitats. Hydropower generation occurs in the sage-grouse range in parts of Washington State. Conventional hydropower electrical generation has actually decreased over the past 5 years (EIA in litt. 2008). Two new developments in Washington are forecast, but do not have implementation dates (FWS in litt. 2008d).

Renewable Energy Development (Wind Energy): Areas of commercially viable wind generation have been identified by the National Renewable Energy Laboratory (NREL in litt. 2008) and BLM (2005, p. 2.4) in all 11 states in the range (Figure 9).

Figure 9: Wind Potential within the Sage-grouse Conservation Assessment Boundary (reater sage-grouse range plus a buffer, as defined by Connelly et al., 2004).

Wind Potential within the Sage-grouse Conservation Assessment Boundary



In Management Zones III through VII, including the States of Washington, Oregon, Idaho, Nevada, Utah and Colorado, approximately 1 to 14 percent of sagebrush habitats have commercially developable wind energy potential (Table 6). Wind harvesting potentials are more concentrated and geographically extensive in sage-grouse

Management Zones I and II that include parts of Montana, Wyoming, North Dakota and South Dakota; areas of highest commercial potential include 59 percent of the available sagebrush habitats in these four states (Table 6).

Table 6: Area of sagebrush habitat with wind energy development potential by greater sage-grouse Management Zone.

Sage-grouse Management Zone	Total Sagebrush Area	Area of Sagebrush with developable wind potential	
	(acres)	(acres)	(percent)
I	44,771,528	34,034,787	76.02
II	27,452,132	11,573,453	42.16
III	23,178,092	748,172	3.23
IV	35,382,977	3,200,902	9.05
V	16,531,681	1,367,418	8.27
VI	4,554,305	657,442	14.44
VII	4,475,260	49,162	1.10
Totals	**156,345,974**	**51,631,336**	**33.02**

Commercial viability is based on wind intensity and consistency, available market and access to transmission facilities. Consequently, current development is focused in areas with existing distribution infrastructure associated with urban development, preexisting conventional energy resource development (e.g. coal and natural gas) and power generation. Based on news reports, industry publications and government projections, wind power development is expected to continue at a fast rate (wind-watch.org, accessed October 6, 2008; SustainableBusiness.com, accessed October 6, 2008; dsireusa.org, accessed October 6, 2008; EIA 2008, p. 24; DOE in litt. 2007). Additional growth is expected, spurred by statutory mandates or financial incentives to use renewable energy sources in all 11 states (AFWA and FWS 2007, pp. 7, 8, 14, 28, 30, 36, 39, 43, 46, 49, 52; Oregon.gov/ENERGY/RENEW/RPS_home.shtml, accessed October 18, 2008).

Since the beginning of 2005, electricity production from all wind generating facilities has increased 130 percent from approximately 14,000,000 to over 32,000,000 thousand Kilowatthours (EIA in litt. 2008). Wind generating facilities have increased in size and number outpacing development of other renewable sources in the sage-grouse range. Over 20,000 wind turbines and an additional 130,000 acres with an unknown number of turbines are developed or under development in the 11 states comprising the extant range of the sage-grouse (Table 7). This is an increase of over 5,300 turbine units since the end of 2004. Not all of the wind power development is in sagebrush habitats however. Units in sagebrush habitats have increased from approximately 275 in 2005 to 2,700 in 2008. Conservative estimates of exiting production or farms in development in sagebrush habitats include 1,509 turbine units in Wyoming (Management Zone I and II), 103 in Montana (Management Zone I), 430 in Idaho (Management Zone IV), 202 in Oregon (Management Zone IV and V), 721 in Washington (Management Zone VI), and an unknown number of turbines on approximately 40,000 acres in Nevada (Management Zones III, IV and V) (FWS in litt. 2008a; awea.com, accessed September 3, 2008; wind-watch.org, accessed September 6, 2008).

Table 7: Wind energy development in the greater sage-grouse range from 2004 to 2008.

State	Management Zone	2004 Turbine Units	2008 Turbine Units or acres	2005 to 2008 New units or acres in

						sagebrush
		total	in sagebrush	total	in sagebrush	
North Dakota	1	44	0	298	0	0
South Dakota	1	34	0	164	0	0
Montana	1	1	0	132	103	103
Wyoming	1 and 2	273	273	1,552	1,509	1,236
Utah	2, 3, 4 and 7	1	0	11	unknown	unknown
Idaho	4	2	2	528	432	430
Nevada	3, 4 and 5	0	0	128,970 ac	39,680 ac estimated	39,680 ac estimated
California	3 and 5	13,590	0	13,917	0	0
Oregon	4 and 5	320	0	1,136	202	202
Washington	6	317	0	1,521	721	721
Colorado	2 and 7	190	0	822	0	0

An increase in wind energy development is most notable within the range of the south-central Wyoming subpopulation in Management Zone II. This sub-population has a loose association with adjacent populations where there is accelerated oil, gas and coal development in the state – the Powder River Basin (Management Zone I) to the northeast and Pinedale/Jonah Fields in the southwest Wyoming Basin (Connelly et al. 2004, p. 6-62). As stated previously, the Powder River Basin is home to an important regional population of the larger Wyoming Basin population (Connelly et al. 2004, p. 6-62). The sub-population in southwest Wyoming and northwest Colorado is a stronghold for sage-grouse with some of the highest estimated densities of males per square kilometer anywhere in the remaining range of the species (Connelly et al. 2004, pp. 6-62, A5-23). The south-central Wyoming wind potential corridor is not only a geographical bridge between two important population areas but is home to a high population of sage-grouse (Connelly et al. 2004, p. A5-22) and core areas identified preliminarily as important breeding areas for sage-grouse by the Wyoming State Governor's Sage-Grouse Implementation Team (http://governor.wy.gov/press-releases/executive-order-on-sage-grouse-coordinates-agencies-to-protect-grouse-habitat-in-wyoming.html, accessed October 19, 2008).

Renewable energy resources including wind power require many of the same features for construction and operation as do non-renewable energy resources. Therefore, we anticipate that potential impacts from direct habitat losses, habitat fragmentation through roads and powerlines, noise, and increased human presence (Connelly et al. 2004, pp. 7-40, 7-41) will generally be the same as already discussed for nonrenewable energy development.

Wind farm development begins with site monitoring and collection of meteorological data to accurately characterize the wind regime. Turbines are installed after the meteorological data indicate the appropriate siting and spacing. Roads are necessary to access the turbine sites for installation and maintenance. Each turbine unit has an estimated footprint of 0.4 to 1.2 ha (1 to 3 ac) (BLM 2005a, pp. 3.1-3.4). One or more substations may be constructed depending on the size of the park. Substation footprints are 2 ha (5 acres) or less in size (BLM 2005a, p. 3.7). Unit dimensions may vary, but typical commercial-grade power generation turbines have 100 m (328 ft) tower height, 100 m (328 ft) rotor diameter, 150 m (492 ft) peak height, and 50 m (164 ft) blade tip above the ground height (aweo.org, accessed October 6, 2008).

The average footprint of a turbine unit is relatively small from a landscape perspective. Turbines require careful placement within a field to avoid loss of output from interference with neighboring turbines. This "wind park effect" is avoided by separating units by 3 to 5 rotor diameters perpendicular to the wind and 5 to 10 rotor diameters parallel to the wind (windpower.org, accessed October 6, 2008). Spacing improves efficiency but expands the overall footprint of the field. Direct habitat loss would increase primarily from extension of access roads, and habitat effectiveness could decrease due to avoidance.

Wind power mortalities may result from sage-grouse flying into turbine rotors or towers (Erickson et al. 2001, total) although reported collision mortalities have been few. One sage-grouse was found dead within 45 m (148 ft) of a turbine on the Foote Creek Rim wind facility in south-central Wyoming, presumably from flying into a turbine (Young et al. 2003, appendix C p. 61). During a three year monitoring operation, this is the only known sage-grouse mortality at this facility. Sage-grouse hens with broods have been observed using Foote Creek Rim, under the turbines, during surveys for other species (Young 2004). We have no recent reports of sage-grouse mortality due to collision with a wind turbine, however many facilities may not be monitored. No deaths of gallinaceous birds were reported in a comprehensive review of avian collisions and wind farms in the United States; the authors hypothesized that the average tower height and flight height of grouse, and diurnal migration habitats of some birds minimized the risk of collision (Johnson et al. 2000, pp. ii-iii; Erickson et al. 2001, pp. 8, 11, 14, 15).

Noise is produced by wind turbine mechanical operation (gear boxes, cooling fans) and airfoil interaction with the atmosphere. Character of the sound varies with turbine speed and atmospheric conditions. Different arrangements of multiple wind turbines would result in different noise levels. Topography can also affect noise level and reach. No published studies have focused specifically on the effects of wind development and greater sage-grouse. In studies conducted in oil and gas fields, noise may have played a factor in habitat selection and decrease in lek attendance (Holloran 2005, pp. 49, 56). However, comparison between wind turbine and oil and gas operations is difficult based on the character of sound. Adjusting for manufacturer type and atmospheric conditions, the audible operating sound of a single wind turbine has been calculated as the same level as conversational speech at 1 m (3 ft) at a distance of 600 m (2,000 ft) from the turbine. This level is typical of background levels of a rural environment (BLM 2005a, p. 5-24). Commercial wind farms do not have a single turbine, however, and multiple turbines over a large area would likely have a much larger noise print. Low-frequency vibrations produced by rotating blades produce annoyance responses in humans (Leventhal 2003, p. 28), but the specific effect on birds is not documented.

Moving blades of turbines cast moving shadows that cause a flickering effect producing a phenomenon called "shadow flicker" (windpower.org, accessed October 6, 2008). Hypothetically, shadow flicker could mimic predator shadows and elicit an avoidance response during daylight hours, but this has not been investigated.

Since 2005, renewable portfolio standards have been instituted by policy or statute to include renewables as a percentage of energy consumed in a state. For example: Colorado law requires incremental increases of renewable generation from 3 percent in 2007 to 20 percent by 2020. Financial incentive, including grants and tax breaks, are applied to encourage private development of renewable sources. Although development of renewables is encouraged at a state level, siting authority for wind vary from state to state (AFWA and FWS 2007 pp. 7, 8, 14, 28, 30, 36, 39, 43, 46, 49, 52; Oregon.gov/ENERGY/RENEW/RPS_home.shtml, accessed October 18, 2008). For example: Wyoming has no renewable portfolio standard and no specific wind siting authority. Large projects are subject to approval by an industrial siting committee with the state wildlife agency providing recommendations for mitigating impacts to wildlife. The State of Idaho provides tax incentives and loan programs for renewable energy development and wind power is currently unregulated at any level of government. North Dakota Public Service Commission regulates siting of wind power facilities over 100 Megawatts using U.S. Fish and Wildlife Service interim guidelines.

In 2005, the BLM completed the Wind Energy Final Programmatic Environmental Impact Statement (EIS) that provides an overarching guidance for wind project development on BLM administered lands. Best management practices (BMP) are prescribed to minimize impacts of all phases of construction and operation of a wind production facility. The BMPs guide future project planning and do not guarantee protections specific to sage-grouse. We do not have information on how or where the EIS guidance has been applied since 2005 and can not evaluate its effectiveness.

The footprint of wind energy developments is reported to be small. The BLM indicates that approximately 600 km^2 (148,000 ac) of BLM administered lands are likely to be developed in nine states within the sage-grouse range (BLM 2005a, p. 5-2). It is estimated that only 5 to 10 percent of a development will have a long-term disturbance (i.e. roads, foundations, substation, fencing) (BLM 2005a, p. 5-2). This estimation does not account for avoidance and could be an underestimation of indirect effects. Based on what we know of oil and gas development (previously described), the impact of structures, noise and human activity reach far beyond the point of origin.

Renewable Energy Development (Hydropower): Hydropower development causes direct habitat losses and possibly an increase in human recreation activity. More than 400 dams have been constructed on the Columbia River system alone for power generation. Reservoirs created concurrently with power generation structures inundated hundreds of kilometers of riparian habitats used by sage-grouse broods (Braun 1998, p. 6). Reservoirs and the availability of irrigation water precipitated conversion of large expanses of upland shrub-steppe habitat in the Columbia Basin adjacent to the rivers (65 FR 51578). We were unable to find any information regarding the amount of sage-grouse habitat affected by hydropower projects in other areas of the species range beyond the Columbia Basin. To our knowledge, no new facilities have been constructed since our 2005 finding (FWS in litt. 2008a). We do not anticipate that future dam construction will result in large losses of sagebrush habitats.

Renewable Energy Development (Solar Power): Solar powered electricity generation is increasing. In 2005, 66 trillion Btu were produced from both types of solar electricity generation, and the first half of 2008 indicates a total of 82 trillion Btu will be produced for the year (EIA in litt. 2008). Harvesting of solar energy to produce electricity is accomplished by photovoltaic or concentrating systems. Photovoltaic systems have been used on a small scale to power individual buildings, small complexes, remote facilities, and signs. Voltaic infrastructure is ancillary to other development, and in itself does not contribute to a direct habitat loss. Concentrating systems achieve commercial-scale electrical production by powering turbines using heat-concentrating mirrors. Concentrating systems require, depending on local conditions, 4 acres to produce 1 megawatt of electricity. For example, the 400-acre Nevada Solar One, the third largest solar electricity producer in the world, has a maximum potential of 75 megawatts from a 300-acre solar field (nevadasolarone.net, accessed October 7, 2008). There are no commercial solar plants operating in sage-grouse habitats. Southern and eastern Nevada, the Pinedale area of Wyoming, and east central Utah are the areas of the sage-grouse range with good potential for commercial solar development (tonto.eia.doe.gov/state, accessed October 7, 2008) and could be targeted for development in the future. We are not aware of any investigations reporting the impacts of solar generating facilities to sage-grouse or other gallinaceous birds. Commercial solar generation could produce direct habitat loss (i.e. solar fields completely eliminate habitat), fragmentation, roads, powerlines, increased human presence, and disturbance during facility construction with similar effects to sage-grouse as reported with oil and gas development. The BLM is developing a programmatic EIS for leasing and development of solar energy on BLM lands.

Renewable Energy Development (Geothermal): The major commercial use of geothermal resources is electricity production. Overall geothermal energy production has remained steady since 2005 (EIA in litt. 2008). Facilities are in place in the sage-grouse range in California (3 plants, Management Zone III), Nevada (5 plants, Management Zones III and V), Utah (2 plants, Management Zones III), and Idaho (1 plant, Management Zone IV). Four new plants in Nevada and one in Idaho came on line since 2005, but only the Idaho plant is in current sage-grouse range (geo-energy.org, accessed October 8, 2008). We have no information on the footprint of the Idaho facility. Geothermal potential occurs across the sage-grouse range in states with existing development and southeast Oregon, west central Wyoming, and north central Colorado (tonto.eia.doe.gov, accessed October 8, 2008).

Geothermal is similar to oil and gas development requiring surface exploration, exploratory drilling, field development, plant construction and operation. Wells are drilled to access the thermal source and could take 3 weeks to 2 months of continuous drilling (Suter 1978, p. 3). The ultimate number of wells depends on the thermal output of the well and expected production of the plant (Suter 1978, p. 3). Pipelines are needed to carry steam or superheated liquids to the generating plant which is similar in size to a coal or gas-fired plant. Direct habitat loss occurs from well pads, structures, roads, pipelines and transmission lines and impacts would be similar to those described previously for oil and gas development.

The development of geothermal energy requires intensive human activity during field development and operation. Geothermal plants could be in remote areas necessitating housing construction, transportation and utility infrastructure for employees and their families (Suter 1978, p. 12). Geothermal development could cause toxic gas release; the type and effect of these gases depends on the geological formation in which drilling occurs (Suter 1978, pp. 7-9). The amount of water necessary for drilling and condenser cooling may be high. Local water depletions may be a concern if such depletions result in the loss of brood-rearing habitat.

Renewable Energy Development (Biomass): Energy production from biomass has occurred at a consistent rate since 1975 (eia.doe.gov/overview, accessed October 8, 2008). Wood has been the primary biomass source, but corn ethanol and biofuels are on the increase (eia.doe.gov/overview, accessed October 8, 2008). Currently, wood products and corn production do not occur in the range of the sage-grouse in significant quantities (Curtis 2008, p.7). The National Renewable Energy Laboratory cites potentials for agricultural biomass resources in northern Montana (Management Zone I), southern Idaho (Management Zone IV), eastern Washington (Management Zone VI), eastern

Oregon Management Zone IV), northwest Nevada (Management Zone V), and southeast Wyoming (Management Zone II) (NREL in litt. 2005). Conversion from native sod to agriculture for the purpose of biomass production could result in a loss of sage-grouse habitat on private lands.

Energy Corridors: Section 368(a) of the Energy Policy Act of 2005 (42 USC 15926) directs federal land management agencies to designate corridors on federal land in 11 western states for oil, gas and hydrogen pipelines and electricity transmission and distribution facilities (energy transport corridors). The agencies are preparing a programmatic environmental impact statement (PEIS), "Designation of Energy Corridors on Federal Land in the 11 Western States" (DOE et al. 2007) to address the environmental impacts of a corridor on federal lands. The proposed action calls for designating more than 9,600 km (6,000 mi) with and average width of 1 km (3,500 ft) of energy corridors across the West (DOE et al. 2007, p. ES-8). The designated corridors on federal lands will tie-in to corridors on private lands and lands in other governmental jurisdictions. Some of the areas proposed for designation are currently used for transmission. Federal land not presently in transportation or utility right-of-way is proposed for use in California (301 km or 187 mi), Colorado (189 km or 117 mi), Idaho (343 km or 213 mi), Montana (9.8 km or 6 mi), Nevada (1,416 or 880 mi), Oregon (140 km or 225 mi), Washington (6 km or 4 mi), Utah (473 km or 294 mi), and Wyoming (204 km or 127 mi) (DOE et al. 2007, p. ES-14). It is uncertain how much of the corridor is in sagebrush habitat within the distribution area of sage-grouse, but based on the proposed location, habitat in Wyoming (Management Zone II), Idaho (Management Zone IV), Utah (Management Zone III), Nevada (Management Zone III) and Oregon (Management

Zone III and IV) would be most affected. Sage-grouse could be impacted through a direct loss of habitat, human activity (especially during construction periods), increased predation, habitat deterioration through the introduction of nonnative plant species, and fragmentation of habitat.

Measures to minimize energy development effects: The BLM is the primary federal agency managing the U.S. energy resources on 261 million surface acres and 700 million sub-surface acres of mineral estate. Public sub-surface estate can be under public or private (i.e. split-estate) surface. Over 18 million acres of sage-grouse habitats on public lands are leased for oil, gas, coal, minerals or geothermal exploration and development across the sage-grouse range (FWS in litt. 2008c).

The BLM has the legal authority to regulate and condition oil and gas lease and permits under both Federal Land Policy and Management Act (FLPMA) (43 USC 1764) and the Mineral Leasing Act (MLA) (30 USC 181 et seq). The Energy Policy and Conservation Act (EPCA) of 2000 included provisions requiring the Secretary of the Interior to conduct a scientific inventory of all onshore Federal lands to identify oil and gas resources underlying these lands and the nature and extent of any restrictions or impediments to the development of such resources (42 USC 6217(a)). The Energy Policy Act was amended as the Energy Policy and Conservation Act (EPCA) in 2005 (42 USC 6201 et seq.). Provisions of earlier Energy Policy Acts were further mandated in 2005 to increase development of renewable and nonrenewable energy resources.

On May 18, 2001, the President signed Executive Order 13212 – Actions to Expedite Energy-Related Projects (E.O. 13212) (66 FR 28357, May 22, 2001), which states that it is the Administration's policy that the executive departments and agencies shall take appropriate actions, to the extent consistent with applicable law, to expedite projects that will increase the production, transmission, or conservation of energy. The Executive Order specifies that this includes expediting review of permits or taking other actions as necessary to accelerate the completion of projects, while maintaining safety, public health, and environmental protections. The BLM responded to these declarations with the issuance of several Instruction Memoranda to their staff that may influence sage-grouse conservation during these actions, including providing guidance for land use planning relative to oil and gas operations and focusing efforts for resource recovery in seven areas, six of which are within occupied greater sage-grouse habitats (BLM IM 2003-137, April 3, 2003).

On September 25, 2007, the BLM issued Information Bulletin WO-2007-119 – Existing Surface Management Authority for Oil and Gas Leases. This Information Bulletin reiterated to field offices that the agency has "broad policy and legal authority for mitigating adverse environmental impacts on oil and gas leases" (BLM in litt. 2008, p. 2). It further stated that the Secretary of Interior has "broad authority to regulate environmental aspects of oil and gas operations," and to "require environmental protection determined necessary or needful" (BLM in litt. 2008c, p. 2).

Program-specific guidance for fluid minerals (which include oil and gas) in the BLM planning handbook specifies that land use planning decisions will identify restrictions on areas subject to leasing, including closures, as well as lease stipulations (BLM 2005b, appx. C pp.23-24). Stipulations are conditions, promises, or demands that are made part of a lease when the environmental planning record demonstrates the need to accommodate various resources such as the protection of specific wildlife species. Stipulations advise the lease holder that a wildlife species in need of special management may be present in the area defined by the lease, and certain protective measures may be required in order to develop the mineral resource on that lease.

This handbook further specifies that all stipulations must have waiver, exception, or modification criteria documented in the plan, and notes that the least restrictive constraint to meet the resource protection objective should be used (BLM 2005b, appx. C pp.23-24). Waivers, which are permanent exemption, and modifications which are changes in the terms of the stipulation, may require public notices. The BLM reports the issuance of waivers and modifications as rare (BLM in litt. 2008d). Exceptions are a one-time exemption to a lease stipulation. For example, a company may be issued an exception to enter critical winter habitat during mild winter if an on-the-ground survey verifies that sage-grouse are not using the winter habitat or have left earlier than normal (BLM 2004, p. 86). In 2006 and 2007, of 1,716 mineral/right-of-way authorizations on federal surface in 42 BLM planning areas no waivers were issued, 24 modifications were issued, and 115 exceptions were granted; 72 of the 115 exceptions were in the Great Divide planning area in Wyoming (BLM in litt. 2008d).

Although there is some variability in the characteristics of the restrictive stipulations that are applied to permits and leases, a 0.40-km (0.25 mi) radius around sage-grouse leks is generally restricted to “no surface occupancy” during the breeding season, and noise and development activities are often limited during the breeding season within a 0.80 to 3.22-km (0.5 mi to 2-mi) radius of sage-grouse leks. Although these are the most often-applied stipulations, there is a high degree of variability regarding the implementation of stipulations at the site-specific level. For example, language in the Randolph Resource Management Plan (RMP) in Utah states that no exploration, drilling, or other development activities can occur during the breeding season within 3.22 km (2 mi) of a known sage-grouse lek, and that there are “no exceptions to this stipulation” (BLM in litt. 2008e). Conversely, under the Platte River RMP in the Wind River Basin Management Area of Wyoming, “oil and gas development is a priority in the area” and “discretionary timing stipulations protecting sage-grouse nesting habitats…will not be applied” (BLM in litt. 2008e). A majority of the Land Use Plans that address oil and gas or minerals development specify the standard protective stipulations (BLM in litt. 2008e). The stipulations do not apply to the operation or maintenance of existing facilities, regardless of their proximity to sage-grouse breeding areas (BLM in litt. 2008e). In addition, approximately 73 percent of leased land in known sage-grouse breeding habitat has no stipulations at all (BLM in litt 2008f). Breeding habitat is defined as 6.4 km (4 mi) around a known lek point (Wakkinen et al. 1992, p. 2).

As noted above, a 0.4-km (0.25 mi) radius buffer is used routinely by federal agencies and some state agencies to minimize the impacts of oil and gas development on sage-grouse breeding activity. The rationale for using a 0.4 km buffer as the basic unit for active lek protection is not clear. To our knowledge there is no support in published literature for this distance affording any measure of protection. Anecdotally, this distance appears to be an artifact from the 1960's attempt to initiate planning guidelines for sagebrush management and not is not scientifically based (1991 Affidavit by Dave A. Roberts, Wyoming Wildlife Program Leader, BLM in response to Jonah oil and gas field development appeal *in* Colorado Greater Sage-Grouse Conservation Plan 2008, pp. B-5, B-6). Walker (2007, p. 2651) reported negative impacts on lek attendance of coal-bed methane development within 0.8 km (0.5 mi) and 3.2 km (2 mi) of a lek. Holloran (2005, p. 57-60) observed decline of males at leks extending to 6.2 km (3.9 mi) but decline was seen most severely within 5 km (3 mi) of drilling operation and 3 km (2 mi) of producing well and roads.

As with fossil fuel sources, the production, purchase, and facilitation of development of renewable energy products by federal entities and land management agencies is directed by the 2005 EPCA (42 U.S.C. 15852) and Presidential E.O. 13212. The discussion of energy development preceding this section describes in detail the development and operation of renewable energy projects that have occurred since 2005. This includes recent increases in wind, solar, and geothermal energy development. All of these activities require ground disturbance, infrastructure, and ongoing human activities that could adversely affect greater sage-grouse on the landscape. Since 2005, the BLM has developed or is in the process of developing guidance to minimize impacts of renewable energy production on public lands. A Record of Decision (ROD) for "Implementation of a Wind Energy Development Program and Associated Land Use Plan Amendments" (BLM 2005a) was issued in 2005. The ROD outlines Best Management Practices (BMP) for the siting, development and operation of wind energy facilities on BLM lands. The voluntary guidance of the BMPs do not include measures specifically intended to protect greater sage-grouse, although they do provide the flexibility for such measures to be required through site-specific planning and authorization (BLM 2005a, p. 2). Similarly, the BLM is currently in the process of developing programmatic-level guidance for the development of solar and geothermal energy projects. A draft programmatic Environmental Impact Statement (EIS) for geothermal development is currently available, and the draft programmatic EIS for solar energy is under development (BLM in draft, 2008-both available at http://www.blm.gov/wo/st/en/prog/energy/epca_chart.html).

In summary, the BLM manages the majority of the greater sage-grouse habitats across the range of the species. The BLM has broad regulatory authority to plan and manage all land use activities on their lands, including travel management, grazing, fire management, and a variety of other activities. The BLM also has the legal authority to regulate oil, gas, and other energy development activities, both on BLM administered lands, and on split-estate lands. However, research that has emerged since our 2005 finding indicates that stipulations commonly applied by BLM to oil and gas leases and permits do not adequately address the scope of negative influences of development on sage-grouse.

Energy development also occurs on National Forest lands, although to a lesser extent than on BLM lands. Management of activities on National Forest System lands is guided principally by the National Forest Management Act (NFMA) (16 U.S.C. 1600-1614, August 17, 1974, as amended 1976, 1978, 1980, 1981, 1983, 1985, 1988 and 1990). NFMA specifies that all National Forests must have a land and resource management plan (LRMP) (16 U.S.C. 1600) to guide and set standards for all natural resource management activities on each National Forest or National Grassland. Through the NFMA and LRMPs, and the On-Shore Oil and Gas Leasing Reform Act (1987; implementing regulations at 36 CFR 228, subpart E) the USFS has the authority to manage, restrict, or attach protective measures to mineral and other energy permits on USFS lands. Similar to BLM, existing protective standard stipulations on USFS lands include avoiding construction of new wells and facilities within 0.4 km (0.25 mi), and noise or activity disturbance within 3.2 km (2.0 mi) of active sage-grouse leks during the breeding season. As described above recent research shows this is an inadequate buffer to prevent adverse impacts to sage-grouse at a local level. For most LRMPs where energy development is occurring, these stipulations also apply to hard mineral extraction, wind development, and other energy development activities in addition to fluid mineral extraction (e.g., USFS in litt. 2008a, p. 32). The USFS is a partner agency with the BLM on the draft programmatic EIS for geothermal energy development described above. If finalized, the programmatic EIS will amend relevant LRMPs and will expedite the leasing of USFS lands with geothermal energy potential.

In Wyoming, the Governor issued an Executive Order on August 1, 2008, mandating special management for all State lands within sage-grouse "Core Population Areas." Core Population Areas are important breeding areas for sage-grouse in Wyoming as identified by the Wyoming "Governor's Sage-Grouse Implementation Team." In addition to identifying Core Population Areas, the Team also recommended stipulations that should be placed on development activities to ensure that existing habitat function is maintained within those areas. Accordingly, the Executive Order prescribes special consideration for sage-grouse in the Core Population Areas for new developments or land uses, including new oil and gas leases or developments. On August 7, 2008, the Wyoming Board of Land Commissioners approved the application of the Implementation Team's recommended stipulations to all new development activities on State lands within the Core Population Areas. These conservation measures could provide substantial protections for sage-grouse within these Core Population Areas. However, currently these protective measures are only required on previously undeveloped areas on Wyoming State lands. We do not have estimates of the proportion of undeveloped habitat on state lands, or of the percent of sage-grouse populations that will receive the protections of these new measures. Montana, Colorado, and other states are currently considering conservation strategies that use a core area approach to address potential effects of energy development on sage-grouse. However, no states other than Wyoming currently have a regulatory framework developed to require protective measures.

All of the states in the extant range of the greater sage-grouse have finalized conservation or management plans for the species and its habitats. These plans focus on habitat and population concerns at a state level. The degree to which they consider energy impacts varies substantially, with some plans proposing explicit strategies for minerals development (e.g., Montana) or wind energy development (e.g., Washington), and others that more generally acknowledge potential issues with energy development but do not identify specific conservation measures (e.g., Nevada) (Stiver et al. 2006, p. 2-24). These state level plans are not prescriptive, and generally contain information to help guide the development and implementation of more focused conservation efforts and planning at a local level. We recognize the importance of these plans and coordination efforts, but as guidance documents it is difficult to assess the extent to which they alleviate the impacts to sage-grouse associated with energy development activities. We do not have information on the extent to which conservation and mitigation measures that are recommended in the state plans to address the impacts of energy development have been adopted into legal or regulatory frameworks (e.g., Resource Management Plans), or have been implemented on the ground.

In September 2008, the Colorado Oil and Gas Conservation Commission (COGCC) initially approved new wildlife rules to protect wildlife from the impacts of oil and gas development in Colorado (COGCC 2008). Most notably, the new rules would require developers to consult with the Colorado Division of Wildlife if they proposed to drill in a sensitive wildlife habitat area, including sage-grouse habitats. This requirement could be waived if the developer agreed to limit disturbance or development density within the sensitive area. The COGCC is expected to make a final decision on these new rules in December 2008 (COGCC 2008). If implemented, these new rules would provide additional protections to sage-grouse from the impacts of oil and gas development in Colorado.

Habitat—Grazing

Native herbivores, such as pronghorn antelope (*Antilocarpo americana*), bison (*Bison bison*), and other ungulates were present in sagebrush steppe region prior to European settlement of western States (Miller et al. 1994, p. 111), and sage-grouse co-evolved with these animals. However, many areas of sagebrush-steppe did not support herds of large ungulates; large native herbivores disappeared 12,000 years ago (Knick et al. 2003, p, 616). Therefore, native vegetation communities within the sagebrush ecosystem developed in the absence of significant grazing presence (Grayson 1994 as cited in Knick et al. 2003, p. 616). With European settlement of western states (1870 to the early 1900s), the numbers of cattle, sheep, and horses rapidly increased, peaking at the turn of the century (Oliphant 1968, p. vii; Young et al. 1976, pp.194-5) with an estimated 26 million cattle and 20 million sheep in the West (Wilkenson 1992).

Effects on sage-grouse and its habitats: Knick et al. (2003, p. 616) state that excessive grazing by domestic livestock during the late 1800's and early 1900's, along with severe drought, significantly impacted sagebrush ecosystems. Long-term effects from this overgrazing, including changes in plant communities and soils persist today (Knick et al. 2003, p.116). Currently, livestock grazing is the most widespread type of land use across the sagebrush biome (Connelly et al. 2004, p. 7-29); almost all sagebrush areas are managed for livestock grazing (Knick et al. 2003, p. 616).

Although there is little direct experimental evidence linking grazing practices to population levels of greater sage-grouse (Braun 1987, p. 137, Connelly and Braun 1997, p. 231), the impacts of livestock grazing on sage-grouse habitat and on some aspects of the life cycle of the species have been studied.

Sage-grouse need significant grass and shrub cover for protection from predators, particularly during nesting season, and females will preferentially choose nesting sites based on these qualities (Hagen et al. 2007, p. 46). The reduction of grass heights due to livestock grazing in sage-grouse nesting and brood-rearing areas has been shown to negatively affect nesting success by reducing cover (< 18 cm) necessary for predator avoidance (Gregg et al. 1994, p. 164-5). Based on measurements of cattle foraging rates on bunchgrasses both between and under sagebrush canopies, the probability of foraging on under-canopy bunchgrasses depends on sagebrush morphology, and consequently, the effects of grazing on nesting habitats might be site specific (France et al.2008, pp. 392-3).

Livestock consumption of forbs may reduce food availability for sage-grouse. This is particularly important for pre-laying hens, as forbs provide essential calcium, phosphorus, and protein (Barnett and Crawford 1994, p. 117). A hen's nutritional condition affects nest initiation rate, clutch size, and subsequent reproductive success (Barnett and Crawford 1994, p.117; Coggins 1998, p. 30). Several other authors have noted that grazing by livestock could reduce the suitability of breeding and brood-rearing habitat, subsequently negatively affecting sage-grouse populations (Braun 1987, p. 137; Dobkin 1995, p. 18; Connelly and Braun 1997, p. 231; Beck and Mitchell 2000, p. 998-1000). Exclosure studies have demonstrated that domestic livestock grazing reduces water infiltration rates and cover of herbaceous plants and litter, as well as compacting soils and increasing soil erosion (Braun 1998; Dobkin et al. 1998, p. 213). This results in a change in the proportion of shrub, grass, and forb components in the affected area, and an increased invasion of exotic plant species that do not provide suitable habitat for sage-grouse (Miller and Eddleman 2000, p. 19).

Livestock may also compete directly with sage-grouse for rangeland resources. Cattle are grazers, feeding mostly on grasses, but they will make seasonal use of forbs and browse species like sagebrush (Vallentine 2001). Domestic sheep are intermediate feeders making high use of forbs, but also using a large volume of grass and browse species like sagebrush (Vallentine 2001). Pedersen et al. (2003, p. 43) documented sheep consumption of rangeland forbs in areas where sage-grouse occur. The effects of direct competition between livestock and sage-grouse depend on condition of the habitat and the grazing practices, and thus the effects vary across the range of the greater sage-grouse. For example, Aldridge and Brigham (2003, p. 30) suggest that poor livestock management in mesic sites, which are considered limited habitats for sage-grouse in Alberta (Aldridge and Brigham 2002, p. 441), results in a reduction of forbs and grasses available to sage-grouse chicks, thereby affecting chick survival.

Other consequences of grazing include several related to livestock trampling. Outright nest destruction by livestock trampling has been documented and the presence of livestock can cause sage-grouse to abandon their nests (Rasmussen and Griner 1938, p. 863; Patterson 1952, p. 111; Call and Maser 1985, p. 17, Holloran and Anderson 2003, p. 309; Coates 2007, p.28). Coates (2007, p. 28) video-monitored 87 grouse nests and recorded six encounters with cattle. During one encounter the nest was partially depredated by the cow, and the nest was subsequently abandoned (Coates 2007, p. 28). All encounters with cattle resulted in hens flushing from nests, which could expose the eggs to predation; there is strong evidence that visual predators like ravens use hen movements to locate sage-grouse nests (Coates 2007, p.33). Livestock may also trample sagebrush seedlings, thereby removing a source of future sage-grouse food and cover (Connelly et al. 2000a). Trampling of soil by livestock can reduce or eliminate biological soil crusts making these areas susceptible to cheatgrass invasion (Mack 1981 as cited in Miller and Eddleman 2000; Young and Allen 1997; Forman and Alexander 1998).

Some effects of livestock grazing may have positive consequences for sage-grouse. Evans (1986, p. 67) found that sage-grouse used grazed meadows significantly more during late summer than ungrazed meadows because grazing had stimulated the regrowth of forbs. Klebenow (1981, p. 121) noted that sage-grouse sought out and used openings in meadows created by cattle grazing in northern Nevada. Also, both sheep and goats have been used to control invasive weeds (Mosely 1996 as cited in Connelly et al. 2004; Olsen and Wallander 2001, p. 30; Merritt et al. 2001, p. 4) and woody plant encroachment (Riggs and Urness 1989, p. 358) in sage-grouse habitat.

Sagebrush removal: Removal of sagebrush to increase herbaceous forage and grasses for domestic and wild ungulates is a common practice in sagebrush ecosystems (Connelly et al. 2004, p. 7- 28). By the 1970s, over 2 million ha (5 million ac) of sagebrush had been mechanically treated, sprayed with herbicide, or burned (Crawford et al. 2004). Braun (1998) concluded that since European settlement of western North America, all sagebrush habitats used by greater sage-grouse have been treated in some way to reduce shrub cover. The use of chemicals to control sagebrush was initiated in the 1940s and intensified in the 1960s and early 1970s (Braun 1987). Crawford et al. (2004, p. 12) hypothesized that reductions in sage-grouse habitat quality (and possibly sage-grouse numbers) in the 1970's may have been associated with extensive rangeland treatments to increase forage for domestic livestock.

The extent to which mechanical and chemical removal or control of sagebrush currently occurs is not known, particularly with regard to private lands. However, the

BLM has stated that with rare exceptions, they no longer are involved in actions that convert sagebrush to other habitat types, and that mechanical or chemical treatments in sagebrush habitat on BLM lands currently focus on improving the diversity of the native plant community, reducing conifer encroachment, or reducing the risk of a large wildfire (BLM 2004, p. 15).

Greater sage-grouse response to herbicide treatments depends on the extent to which forbs and sagebrush are killed. Chemical control of sagebrush has resulted in declines of sage-grouse breeding populations through the loss of live sagebrush cover (Connelly et al. 2000a). Herbicide treatment also can result in sage-grouse emigration from affected areas (Connelly et al. 2000a), and has been documented to have a negative effect on nesting, brood carrying capacity (Klebenow 1970), and winter shrub cover essential for food and thermal cover (Pyrah 1972 and Higby 1969 as cited in Connelly et al. 2000a). Conversely, small treatments interspersed with non-treated sagebrush habitats did not affect sage-grouse use, presumably due to minimal effects on food or cover (Braun 1998). Also application of herbicides in early spring to reduce sagebrush cover may enhance some brood-rearing habitats by increasing the coverage of herbaceous plant foods (Autenrieth 1981).

Mechanical treatments are designed to either remove the aboveground portion of the sagebrush plant (mowing, roller chopping, and roto-beating), or to uproot the plant from the soil (grubbing, bulldozing, anchor chaining, cabling, railing, raking, and plowing; Connelly et al. 2004). These treatments were begun in the 1930s and continued at relatively low levels to the late 1990s (Braun 1998). Mechanical treatments, if carefully designed and executed, can be beneficial to sage-grouse by improving herbaceous cover, forb production, and re-sprouting of sagebrush (Braun 1998). However, adverse effects also have been documented (Connelly et al. 2000a). For example, in Montana, the number of breeding males declined by 73 percent after 16 percent of the 202 km^2 (78 mi^2) study area was plowed (Swenson et al. 1987). Mechanical treatments in blocks greater than 100 ha (247 ac), or of any size seeded with exotic grasses, degrade sage-grouse habitat by altering the structure and composition of the vegetative community (Braun 1998).

The elimination of sagebrush usually is followed with rangeland seedings to improve forage for livestock grazing operations (Knick et al. 2003, p. 616; Connelly et al. 2004, Chapter 7, p. 35). Large expanses of sagebrush removed via chemical and mechanical methods have been reseeded with non-native grasses, such as crested wheatgrass (*Agropyron cristatum*), to increase forage production on public lands (Shane et al. 1983, cited in Knick et al. 2003, p. 616 ; Connelly et al. 2004, p.7-28). These treatments had the effect of reducing or eliminating many native grasses and forbs present prior to the seedings. Sage-grouse are affected indirectly through the loss of native forbs that serve as food and the loss of native grasses that provide concealment or hiding cover within the understories of the former sagebrush stands (Connelly et al. 2004).

Water development: Water developments for the benefit of livestock and wild ungulates on public lands are common (Connelly et al. 2004, p. 7-35). Development of springs and other water sources to support livestock in upland shrub-steppe habitats can artificially concentrate domestic and wild ungulates in important sage-grouse habitats, thereby exacerbating grazing impacts in those areas such as through vegetation trampling (Braun 1998). Diverting the water sources has the secondary effect of changing the habitat present at the water source before diversion. This could result in the loss of either riparian or wet meadow habitat important to sage-grouse as sources of forbs or insects. Water developments for livestock also could be used as mosquito breeding habitat, and thus have the potential to facilitate the spread of West Nile virus (see discussion of Natural Enemies below).

Aldridge et al. (2008) did not find any relationship between sage-grouse persistence and livestock densities (p. 990). However, the authors noted that livestock numbers do not necessarily correlated with range condition. They concluded that the intensity, duration and distribution of livestock are more influential on rangeland condition than the livestock density values used in their modeling efforts (Aldridge et al. 2008, p. 990).

Horses and burros: Free-roaming horses and burros have been a component of sagebrush and other arid communities since they were brought to North America at the end of the 16th century (Wagner 1983, p. 116; Beever 2003, p. 887). About 31,000 wild horses occur in 10 western States, with herd sizes being largest in Nevada, Wyoming, and

Oregon, which are the states with the most extensive sagebrush cover (Connelly et al. 2004, p. 7-37). About 5,000 burros occur in five western states (Connelly et al. 2004, p.7- 37). Beever and Aldridge (2008, in press) estimate that about 12 percent (78, 389km^2) of sage-grouse habitat is managed for free-roaming horses and burros. The extent, however, that the equids use land outside of designated management areas is difficult to quantify but may be considerable.

We are unaware of any studies that directly address the impact of wild horses or burros on sagebrush and sage-grouse. However, some authors have suggested that wild horses could negatively impact important meadow and spring brood-rearing habitats used by sage-grouse (Crawford et al. 2004; Connelly et al. 2004, p. 7-37). Horses are generalists, but seasonally their diets can be almost wholly comprised of grasses (Wagner 1983, p.119-120). A comparison of areas with and without horse grazing showed 1.9-2.9 times more grass cover and higher grass density in areas without horse grazing (Beever 2008, in Beever and Aldridge 2008, in press). Additionally, sites with horse grazing had less shrub cover and more fragmented shrub canopies. As noted above, sage-grouse need significant grass and shrub cover for protection from predators, particularly during nesting season, and females will preferentially choose nesting sites based on these qualities (Hagen et al. 2007, p. 46). Sites with grazing also generally showed less plant diversity, altered soil characteristics, and 1.6-2.6 times greater abundance of non-native cheatgrass (Beever 2008, in Beever and Aldridge 2008, in press). These impacts combined indicate that horse grazing has the potential to result in an overall decrease in the quality and quantity of sage grouse habitat in areas where such grazing occurs.

Currently there are an estimated 315-433 thousand AUMs for equids compared to over 7 million for domestic livestock within the range of greater sage-grouse (Beever and Aldridge 2008, in press). Cattle typically outnumber horses by a large degree in areas where both occur, however, locally ratios of 2:1 (horse:cow) have been reported (Wagner 1983, p.126). The local effects of ungulate grazing depend on a host of abiotic and biotic factors (e.g., elevation, season, soil composition, plant productivity and composition). There are additional significant biological and behavioral differences that influence the impact of horses as compared to cattle grazing on habitat (Beever 2003, p. 888-890). For example, due to physiological differences, a horse must forage longer and consumes 20 to 65 percent more forage than would a cow of equivalent body mass (Wagner 1983, p. 121; Menard et al. 2002, p.127). Unlike cattle and other ungulates, horses have the ability to crop vegetation close to the ground, potentially limiting or delaying recovery of plants (Menard et al. 2002, p.127). In addition, horses seasonally move to higher elevations, spend less time at water, and range farther from water sources than cattle. Given these differences, along with the confounding factor of past range use, it is difficult to assess the overall impact of horses and cattle on the landscape in general, or on sage-grouse habitat in particular. In areas grazed by both horses and cattle, whether the impacts are synergistic or additive is currently unknown (Beever and Aldridge 2008, in press).

Grazing on Federal lands: Important aspects of livestock operations related to impacts on sage-grouse include stocking levels, season of use, and utilization levels.

Cattle and sheep animal unit months (AUMs; the amount of forage required to feed one cow with calf, one horse, five sheep, or five goats for one month) on all Federal land have declined since the early 1900s (Laycock et al. 1996, p. 3). By the 1940s AUMs on all Federal lands (not just areas occupied by sage-grouse) were estimated to be 14.6 million, increasing to 16.5 million in the 1950s, and gradually declining to 10.2 million by the 1990s (Miller and Eddleman 2000, p. 19). As of 2007, the number of permitted AUMs for BLM lands in states where sage-grouse occur totaled 7,118,989 (Beever and Aldridge 2008, in press, pp. 19-20). We estimate that those permitted AUMs occur on approximately 18,783 BLM grazing allotments that overlap with sage-grouse habitat (Stoner 2008). Since 2005, AUMs permitted on 644 (3.4 percent) of those allotments have been decreased (FWS in litt 2008e). However, BLM tracks the number of AUMs permitted rather than the number of AUMs actually used. The number permitted typically is higher than what is used thus, we do not know how the decrease on paper corresponds to the actual number of AUMs for the last four years. Currently there are an estimated 315-433 thousand AUMs for equids within the range of greater sage-grouse (Beever and Aldridge 2008, in press, p. 20).

Measures to minimize effects of grazing: Knick (2008, p. 30) estimates that about 51 percent of sagebrush habitat within the sage-grouse management zones is BLM-administered land; this includes approximately 249,000 square kilometers (about 61.5 million acres). The Federal Land Policy and Management Act of 1976 (FLPMA) (43 U.S.C. 1701 et seq.) is the primary Federal law governing most land uses on BLM-administered lands. Under the FLPMA the BLM is required to develop land use plans, which are the basis for all actions and authorizations involving BLM-administered lands and resources. Further, land use plans provide a framework and programmatic guidance for implementation (activity) plans, including allotment management plans (AMPs) that address livestock grazing. In addition to FLPMA, BLM has specific regulatory authority for grazing management provided at 43 CFR 4100 (Regulations on Grazing Administration Exclusive of Alaska). Livestock grazing permits and leases contain terms and conditions determined by BLM to be appropriate to achieve management and resource condition objectives on the public lands and other lands administered by the BLM, and to ensure that habitats are, or are making significant progress toward being, restored or maintained for BLM special status species (43 CFR 4180.1(d)). Grazing practices and activities subject to standards and guidelines include the development of grazing related portions of implementation/activity plans, establishment of terms and conditions of permits, leases and other grazing authorizations, and range improvement activities such as vegetation manipulation, fence construction, and development of water.

The State or regional standards for grazing administration must address habitat for endangered, threatened, proposed, candidate, or special status species, and habitat quality for native plant and animal populations and communities (43 CFR 4180.2(d)(4) and (5). The guidelines must address restoring, maintaining or enhancing habitats of BLM special status species to promote their conservation, and maintaining or promoting the physical and biological conditions to sustain native populations and communities (43 CFR 4180.2(e)(9) and (10). BLM is required to take appropriate action not later than the start of the next grazing year upon determining that existing grazing practices or levels of grazing use are significant factors in failing to achieve the standards and conform with the guidelines (43 CFR 4180.2(c)).

In 2004, the BLM stated that 89 percent of lands are meeting habitat standards, or are not meeting standards but appropriate actions have been implemented to ensure significant progress towards the standards (BLM 2004, p. 65). The remaining 11 percent are not meeting standards due to either livestock grazing or other causes. More recently BLM reported that of 6.7 million acres of occupied habitat evaluated specifically for sage-grouse in 2005, approximately 3.1 million acres met the desired habitat condition; 3.6 million acres did not. We do not have further information describing these habitat condition assessments, which habitat criteria were not met, the land use that was likely contributing to those criteria not being met, or specific actions taken to improve habitats. However, BLM did report that the following actions were taken to improve sage-grouse habitat in 2005: changed timing of grazing on 1.6 million acres; rested or suspended grazing on 1.3 million acres; and installed or modified 447 water developments/structures (BLM 2005).

<u>Habitat—Habitat Conversion</u>

Sagebrush is estimated to have covered roughly 120 million ha (296 million ac; Schroeder et al. 2004, p. 365) in western North America, but large portions of that area have been cultivated for the production of agricultural crops (e.g. potatoes, wheat; Schroeder et al. 1999, p.16; 2000, p.11). Western rangelands were converted to agricultural lands on a large scale beginning with the series of Homestead Acts in the 1800s (Braun 1998, Hays et al. 1998, p.26), especially where suitable deep soil terrain and water were available (Rogers 1964, p.13). Connelly et al. (2004, p.5-55) estimated that 24.9 million ha (61.5 million ac) within their assessment area for sage-grouse is now comprised of agricultural lands, although there are areas within the species range that are not sagebrush habitat, and the assessment area is larger than the sage-grouse current distribution. The direct effect of habitat conversion is loss of habitat available for sage-grouse use. The actual effect of this loss will depend on the amount of sagebrush lost, the type of seasonal habitat affected, and the arrangement of habitat lost (large blocks or small patches). There may also be direct impacts to sage-grouse depending on the timing of conversion (e.g. loss of nests, eggs). Indirect effects of agricultural activities adjoining sagebrush habitats include increased predation with a resulting reduced sage-grouse nest success (Connelly et al. 2004, p. 7-23), increased human presence, and potential habitat fragmentation. Adding a 6.9 km (4.3 mi) buffer around agricultural areas (for the potential foraging distance of domestic cats and red foxes (*Vulpes vulpes*)), Connelly et al. (2004, p. 7-24) estimated 115.2 million ha (284.7 million ac) (56 percent) within their assessment area for the greater sage-grouse is influenced by agriculture.

Conversion by geographic area: In some States within the range of the greater sage-grouse there have been large losses of sagebrush shrub-steppe habitats due to agricultural conversion. This loss has been especially apparent in the Columbia Basin of the Northwest (Management Zone VI) and the Snake River Plain of Idaho (Management Zone IV) (Schroeder et al. 2004, p. 370). Hironaka et al. (1983) estimated that 99 percent of basin big sagebrush (*A. t. tridentata*) habitat in the Snake River Plain has been converted to cropland. Prior to European immigrant settlement in the 19th century, Washington had an estimated 42 million ha (103.8 million ac) of shrub-steppe (Connelly et al. 2004). Dobler (1994) estimated that approximately 60 percent of the original shrub-steppe habitat in Washington has been converted to primarily agricultural uses. Deep soils supporting shrub-steppe communities in Washington continue to be converted to agricultural uses (Vander Haegen et al. 2000), resulting in habitat loss. Recent geographical information system analyses indicated that agriculture was the dominant land cover within sagebrush areas of Washington (42 percent) and Idaho (19 percent) (Miller et al., in press). In north central Oregon (Management Zone V), approximately 2.6 million ha (6.4 million ac) of habitat were converted for agricultural purposes, essentially eliminating sage-grouse from this area (Willis et al. 1993). More broadly, across the Interior Columbia Basin of southern Idaho, northern Utah, northern Nevada, eastern Oregon (Management Zone IV) and Washington, approximately 6 million ha (14.8 million ac) of shrub-steppe habitat has been converted to agricultural crops (Altman and Holmes 2000).

Development of irrigation projects to support agricultural production, in some cases conjointly with hydroelectric dam construction, has resulted in additional sage-grouse habitat loss (Braun 1998). The reservoirs formed by these projects impacted native shrub-steppe habitat adjacent to the rivers in addition to supporting the irrigation and direct conversion of shrub-steppe lands to agriculture. The projects precipitated conversion of large expanses of upland shrub-steppe habitat in the Columbia Basin for irrigated agriculture (August 24, 2000; 65 FR 51578). The creation of these reservoirs also inundated hundreds of kilometers of riparian habitats used by sage-grouse broods (Braun 1998). However, other small and isolated reclamation projects (4,000 to 8,000 ha [10,000 to 20,000 ac]) were responsible for three-fold localized increases in sage-grouse populations (Patterson 1952) by providing water in a semi-arid environment which provided additional insect and forb food resources (e.g., Eden Reclamation Project in Wyoming). Benefits of providing water through agricultural activities may now be negated due to the threat of West Nile virus.

Miller et al. (in press) found that 5 percent of the areas occupied by Great Basin sagebrush had been converted to agriculture, urban or industrial areas (Management Zones III and IV). Five percent had also been converted in the wheatgrass-needlegrass-shrubsteppe (Management Zone II, primarily in north-central Wyoming) (Miller et al., in press). In sagebrush steppe habitats, 14 percent of sagebrush habitats had been converted to agriculture, urban or industrial activities (Management Zones II, IV, V, and VI) (Miller et al., in press). Conversions for these three sagebrush habitat types by State are detailed in Table 8.

Table 8: Percent of sagebrush-steppe habitats and percent of agricultural lands within Great Basin sagebrush (as derived from Landfire 2006 vegetation coverage) (from Miller et al. in press).

State	Percent sagebrush	Percent agriculture
Washington	23.7	42.4
Montana	56.2*	7.5*
Wyoming	66.0*	3.4*
Idaho	55.0	18.6
Oregon	64.5	8.6
Nevada	58.7	1.3

Utah	37.6	9.7
California	49.8	8.0
Colorado	40.6	11.8
Total	55.4	10.0

*Analyses did not include sagebrush lands in the eastern portions of Montana and Wyoming.

Aldridge et al. (2008, pp. 990-991) reported that sage-grouse extirpations were more likely to occur in areas where cultivated crops exceeded 25 percent. Their results supported the conclusions of others (e.g. Schroeder 1997; Braun 1998; Aldridge and Brigham 2003) that extensive cultivation and fragmentation of native habitats have been associated with sage-grouse population declines. While sage-grouse may forage on agricultural crops (see discussion below), they avoid landscapes dominated by agriculture (Aldridge et al. 2008; p. 991).

Sagebrush habitat continues to be converted for both dryland and irrigated crop production (65 FR 51578; Braun 1998). Although sagebrush conversion for agricultural activities was recently considered to have minimal impacts on sage-grouse (65 FR 51578), increasing value of wheat and corn crops has increased the amount of new conversions in recent years. For example, approximately 22,650 acres of sagebrush in Montana was converted to tilled agriculture from 2005 through 2007, primarily in the eastern two thirds of the state (Management Zone 1) (Montana FSA 2007). However, in 2008, a single conversion in central Montana totaled between 10,000 and 30,000 acres (Management Zone 1) (Hanebury 2008a). Other large conversions occurred in the same part of Montana in 2008, although these were unquantified (Management Zone 1) (Hanebury 2008b).

Use of agricultural crops by sage-grouse: Although conversion of shrub-steppe habitat to agricultural crops impacts sage-grouse through the loss of sagebrush on a broad scale, some studies report the use of agricultural crops (e.g., alfalfa) by sage-grouse. When alfalfa fields and other croplands are adjacent to extant sagebrush habitat, sage-grouse have been observed feeding in these fields, especially during brood-rearing (Patterson 1952, Rogers 1964, Wallestad 1971, Connelly et al. 1988, Fischer et al. 1997). Connelly et al. (1988) reported seasonal movements of sage-grouse to agricultural crops as sagebrush habitats desiccated during the summer. However, use of irrigated crops may not be beneficial to greater sage-grouse if it increases exposure to pesticides and West Nile virus (see discussions in of disease and pesticides below).

Direct habitat loss and conversion also occurs via numerous other landscape uses, including urbanization, livestock forage production, road building, oil pads, etc. These activities are described in greater detail above. However, we were unable to obtain an estimate of the total amount of sagebrush habitats that have been lost due to these activities.

Habitat—Habitat Fragmentation

Habitat fragmentation is the separation or splitting apart of previously contiguous, functional habitat components of a species. Fragmentation can result from direct habitat losses that leave the remaining habitat in non-contiguous patches, or from alteration of habitat areas that render the altered patches unusable to a species (i.e., functional habitat loss). Functional habitat losses include disturbances that change a habitat's successional state or remove one or more habitat functions, physical barriers that preclude use of otherwise suitable areas, and activities that prevent animals from using suitable habitat patches due to behavioral avoidance.

Sagebrush communities exhibit a high degree of variation in their resistance and resilience to change, beyond natural variation. Resistance (the ability to withstand disturbing forces without changing) and resilience (the ability to recover once altered) generally increase with increasing moisture and decreasing temperatures, and can also be linked to soil characteristics (Connelly et al. 2004). However, most extant sagebrush habitat has been altered since European immigrant settlement of the West (Baker et al. 1976; Braun 1998; Knick et al. 2003; Connelly et al. 2004), and sagebrush habitat continues to be fragmented and lost (Knick et al. 2003) through the factors described below. The cumulative effects of habitat fragmentation have not been quantified over the range of sagebrush and most fragmentation cannot be attributed to specific land uses (Knick et al. 2003). However, in large-scale analysis of the collective effect of anthropogenic features or the 'human footprint' in the western United States, Leu et al. (2008, p. 1130) found that 13 percent of the area was affected in some way by anthropogenic features (i.e. fragmentation). Areas with the lowest 'human footprint' (i.e. no to slight development/use) experienced above average human population growth between 1990 and 2000 and there is significant evidence these areas will experience increasing habitat fragmentation in the future (Leu et al. p. 1133).

Fragmentation of sagebrush habitats has been cited as a primary cause of the decline of sage-grouse populations since the species requires large expanses of contiguous sagebrush (Patterson 1952; Connelly and Braun 1997; Braun 1998; Johnson and Braun 1999; Connelly et al. 2000a; Miller and Eddleman 2000; Schroeder and Baydack 2001; Johnsgard 2002; Aldridge and Brigham 2003; Beck et al. 2003; Pedersen et al. 2003; Connelly et al. 2004; Schroeder et al. 2004). The negative effects of habitat fragmentation have been well documented in numerous bird species, including some shrubsteppe obligates (Knick and Rotenberry 1995, p. 1068-1069). However, prior to 2005 detailed data to assess how fragmentation influences specific greater sage-grouse life history parameters such as productivity, density, and home range was not available. However, more recently several studies have documented negative effects of fragmentation, as a result of oil and gas development and its associated infrastructure (see Energy Development - Non Renewable section above) on lek persistence, lek attendance, winter habitat use, recruitment, yearling annual survival rate, and female nest site choice (Aldridge and Boyce 2007, Doherty et al. 2008, Holloran 2005, Walker et al. 2007). While sage-grouse are dependent on interconnected expanses of sagebrush (Patterson 1952; Connelly et al. 2004), data are not available regarding minimum sagebrush patch sizes to support populations of sage-grouse. Estimating the impact of habitat fragmentation on sage-grouse is complicated by time lags in response to habitat changes, particularly since these long-lived birds will continue to return to altered breeding areas (leks, nesting areas, and early brood-rearing areas) due to strong site fidelity despite nesting or productivity failures (Wiens and Rotenberry 1985).

Powerlines: Power grids were first constructed in the United States in the late 1800s. The public demand for electricity has grown as human population and industrial activities have expanded (Manville 2002), resulting in more than 804,500 km (500,000 mi) of transmission lines (lines carrying > 115,000 volts/115kV) by 2002 within the United States (Manville 2002). A similar estimate is not available for distribution lines (lines carrying < 69,000volts/69kV), and we are not aware of data for Canada. Within their analysis area (i.e., the pre-European settlement distribution of greater sage-grouse, including Canada, plus a 50-km (31.3-mi) buffer (buffer is to allow for external factors that may have contributed to current trends in populations or habitats)), Connelly et al. (2004) state there is a minimum of 15,296 km^2 (5,904 mi^2) of land (less than 1 percent of their assessment area) in transmission powerline corridors, but they could provide no estimate of the density of distribution lines in their assessment area.

Powerlines can directly affect greater sage-grouse by posing a collision and electrocution hazard (Braun 1998; Connelly et al. 2000a), and can have indirect effects by decreasing lek recruitment (Braun et al. 2002), increasing predation (Connelly et al. 2004), fragmenting habitat (Braun 1998), and facilitating the invasion of exotic annual plants (Knick et al. 2003; Connelly et al. 2004). In 1939, Borell reported the deaths of 3 adult sage-grouse as a result of colliding with a telegraph line in Utah (Borell 1939). Both Braun (1998) and Connelly et al. (2000a) report that sage-grouse collisions with powerlines occur, although no specific instances were presented. Other than an unpublished observation reported by Aldridge and Brigham (2003), we were unable to find documentations of other collisions and/or electrocution of sage-grouse resulting from powerlines.

In areas where the vegetation is low and the terrain relatively flat, power poles provide an attractive hunting and roosting perch, as well as nesting stratum for many species of raptors (Steenhof et al. 1993; Connelly et al. 2000a; Manville 2002; Vander Haegen et al. 2002). Power poles increase a raptor's range of vision, allow for greater speed during attacks on prey, and serve as territorial markers (Steenhof et al. 1993; Manville 2002). Raptors may actively seek out power poles where natural perches are limited. For example, within one year of construction of a 596-km (372.5-mi) transmission line in southern Idaho and Oregon, raptors and common ravens (*Corvus corax)* began nesting on the supporting poles (Steenhof et al. 1993). Within 10 years of construction, 133 pairs of raptors and ravens were nesting along this stretch (Steenhof et al. 1993). The increased abundance of raptors and corvids within occupied sage-grouse habitats can result in increased predation. Ellis (1985) reported that golden eagle (*Aquila chryrsaetos*) predation on sage-grouse on leks increased from 26 to 73 percent of the total predation after completion of a transmission line within 200 m (220 yd) of an active sage-grouse lek in northeastern Utah. The lek was eventually abandoned, and Ellis (1985) concluded that the presence of the powerline resulted in changes in sage-grouse dispersal patterns and fragmentation of the habitat. Leks within 0.4 km (0.25 mi) of new powerlines constructed for coalbed methane development in the Powder River Basin of Wyoming had significantly lower growth rates, as measured by recruitment of new males onto the lek, compared to leks further from these lines, which was presumed to be the result of increased raptor predation (Braun et al. 2002). Within their analysis area, Connelly et al. (2004) estimated that the area potentially influenced by additional perches for corvids and raptors provided by powerlines, assuming a 5 to 6.9-km (3.1 to 4.3-mi) radius buffer around the perches based on the average foraging distance of these predators, was 672,644 to 837,390 km^2 (259,641 to 323,317 mi^2), or 32 to 40 percent of their assessment area. The actual impact on the area would depend on corvid and raptor densities within the area. The presence of a powerline may fragment sage-grouse habitats even if raptors are not present. Braun (1998; unpublished data) found that use of otherwise suitable habitat by sage-grouse near powerlines increased as distance from the powerline increased for up to 600 m (660 yd) and based on that unpublished data reported that the presence of powerlines may limit sage-grouse use within 1 km (0.6 mi) in otherwise suitable habitat.

Linear corridors through sagebrush habitats can facilitate the spread of invasive species, such as cheatgrass (Gelbard and Belnap 2003; Knick et al. 2003; Connelly et al. 2004). However, we were unable to find any information regarding the amount of invasive species incursion as a result of powerline construction.

Powerlines are common to nearly every type of anthropogenic habitat use, except perhaps some forms of agricultural development (e.g., livestock grazing) and fire. Although we were unable to find an estimate of all future proposed powerlines within currently occupied sage-grouse habitats, we anticipate that powerlines will increase, particularly given the increasing development of energy resources and urban areas. For example, up to 8,579 km (5,311 mi) of new powerlines are predicted for the development of the Powder River Basin coal-bed methane field in northeastern Wyoming (BLM 2003) in addition to the approximately 9,656 km (6,000 mi) already constructed in that area. Although raptors associated with powerlines may negatively impact individual greater sage-grouse and habitats, we could find no information regarding the effect of this impact on a rangewide basis.

Communication towers: Within sage-grouse habitats, 9,510 new communication towers have been constructed within recent years (Connelly et al. 2004). While millions of birds are killed annually in the United States through collisions with communication towers and their associated structures (guy wires, lights, etc.; Manville 2002), most documented mortalities are of migratory songbirds. We were unable to determine if any sage-grouse mortalities occur as a result of collision with communication towers or their supporting structures, as most towers are not monitored and those that are lie outside the range of the species (Shire et al. 2000; Kerlinger 2000). However, communication towers also provide perches for corvids and raptors (Steenhof et al. 1993; Connelly et al. 2004). We could find no information regarding the potential impacts of communication towers to the greater sage-grouse on a rangewide basis.

Fences: Fences are used to delineate property boundaries and for livestock management (Braun 1998; Connelly et al. 2000a). The effects of fencing on sage-grouse include direct mortality through collisions, creation of predator (raptor) perch sites, the potential creation of a predator corridor along fences (particularly if a road is maintained next to the fence), incursion of exotic species along the fencing corridor, and habitat fragmentation (Call and Maser 1985; Braun 1998; Connelly et al. 2000a; Beck et al. 2003; Knick et al. 2003; Connelly et al. 2004).

Sage-grouse frequently fly low and fast across sagebrush flats and new fences can create a collision hazard (Call and Maser 1985). Thirty-six carcasses of sage-grouse were found near Randolph, Utah, along a 3.2 km (2 mi) fence within three months of its construction (Call and Maser 1985). Twenty-one incidents of mortality through fence collisions near Pinedale, Wyoming, were reported in 2003 to the BLM (Connelly et al. 2004). Fence collisions continue to be identified as a source of mortality (Braun 1998; Connelly et al. 2000a; Oyler-McCance et al. 2001; Connelly et al. 2004), although effects on populations are not understood. Fence posts also create perching places for raptors and corvids, which may increase their ability to prey on sage-grouse (Braun 1998; Connelly et al. 2000b; Oyler-McCance et al. 2001; Connelly et al. 2004). We anticipate that the effect on sage-grouse populations through the creation of new raptor perches and predator corridors into sagebrush habitats is similar to that of powerlines discussed previously (Braun 1998; Connelly et al. 2004). Fences and their associated roads also facilitate the spread of invasive plant species that replace sagebrush plants upon which sage-grouse depend (Braun 1998; Connelly et al. 2000a; Gelbard and Belnap 2003; Connelly et al. 2004). Greater sage-grouse avoidance of habitat adjacent to fences, presumably to minimize the risk of predation, effectively results in habitat fragmentation even if the actual habitat is not removed (Braun 1998). More than 1,000 km (625 mi) of fences were constructed annually in sagebrush habitats from 1996 through 2002, mostly in Montana, Nevada, Oregon and Wyoming (Connelly et al. 2004). Over 51,000 km (31,690 mi) of fences were constructed on BLM lands supporting sage-grouse populations between 1962 and 1997 (Connelly et al. 2000a). However, some of the new 1-3 wire fencing being erected across the range may pose less of a collision risk to sage grouse than woven fences.

Roads and Railroads: Impacts from roads may include direct habitat loss, direct mortality, barriers to migration corridors or seasonal habitats, facilitation of predators and spread of invasive vegetative species, and other indirect influences such as noise (Forman and Alexander 1998). Interstates and major paved roads cover approximately 14,272 km^2 (22,835 mi^2) less then 1 percent of their assessment area (Connelly et al. 2004). Secondary paved road densities within this area range to greater than 2 km/km^2 (3.24 mi/mi^2). Sage-grouse mortality resulting from collisions with vehicles does occur (Patterson 1952), but mortalities are typically not monitored or recorded. Therefore, we are unable to determine the importance of this factor on sage-grouse populations. Data regarding how roads affect seasonal habitat availability for individual sage-grouse populations by creating barriers and the ability of greater sage-grouse to reach these areas were not available. Road development within Gunnison sage-grouse habitats precluded movement of local populations between the resultant patches, presumably to minimize their exposure to predation (Oyler-McCance et al. 2001).

Roads can provide corridors for predators to move into previously unoccupied areas. For some mammalian species, dispersal along roads has greatly increased their distribution (Forman and Alexander 1998; Forman 2000). Corvids also use linear features such as primary and secondary roads as travel routes, expanding their movements into previously unused regions (Connelly et al. 2000b; Aldridge and Brigham 2003; Connelly et al. 2004). In an analysis of anthropogenic impacts, Connelly et al. (2004) reported that at least 58 percent of their analysis area has a high or medium presence of corvids. Corvids are important sage-grouse nest predators and in a study in Nevada were positively identified via video recorder as responsible for >50 percent of nest predations (Coates 2007, pp.26-30) Additionally, highway rest areas provide a source of food and perches for corvids and raptors, and facilitate their movements into surrounding areas (Connelly et al. 2004). It has not been documented that sage-grouse populations are affected by predators using roads as corridors into sagebrush habitats.

The presence of roads also increases human access and their resulting disturbance effects in remote areas (Forman and Alexander 1998; Forman 2000; Connelly et al. 2004). Increases in legal and illegal hunting activities resulting from the use of roads built into sagebrush habitats have been documented (Patterson 1952; Connelly et al. 2004). However, the actual current effect of these increased activities on sage-grouse populations has not been determined. Roads may also facilitate access for habitat treatments (Connelly et al. 2004), resulting in subsequent direct habitat losses. New roads are being constructed to support development activities within the greater sage-grouse extant range. For example, in the Powder River Basin of Wyoming, up to 28,572 km (17,754 mi) of roads to support coalbed methane development are proposed (BLM 2003).

The expansion of road networks has been documented to contribute to exotic plant invasions via introduced roadfill, vehicle transport, and road maintenance activities (Forman and Alexander 1998; Forman 2000; Gelbard and Belnap 2003; Knick et al. 2003; Connelly et al. 2004). Invasive species are not limited to roadsides (or verges), but have also encroached into the surrounding habitats (Forman and Alexander 1998; Forman 2000; Gelbard and Belnap 2003). In their study of roads on the Colorado Plateau of southern Utah, Gelbard and Belnap (2003) found that improving unpaved four-wheel drive roads to paved roads resulted in increased cover of exotic plant species within the interior of adjacent plant communities. This effect was associated with road construction and maintenance activities and vehicle traffic, and not with differences in site characteristics. The incursion of exotic plants into native sagebrush systems can negatively affect greater sage-grouse through habitat losses and conversions (see further discussion above).

Additional indirect effects of roads may result from birds' behavioral avoidance of road areas because of noise, visual disturbance, pollutants, and predators moving along a road. The absence of screening vegetation in arid and semiarid regions further exacerbates the problem (Suter 1978). Male lek attendance was shown to decline within 3 km (1.9 mi) of a methane well or haul road with traffic volume exceeding 1 vehicle per day (Holloran 2005, p. 40). Male sage-grouse depend on acoustical signals to attract females to leks (Gibson and Bradbury 1985; Gratson 1993). If noise interferes with mating displays, and thereby female attendance, younger males will not be drawn to the lek and eventually leks will become inactive (Amstrup and Phillips 1977; Braun 1986). Dust from roads and exposed roadsides can damage vegetation through interference with photosynthetic activities; the actual amount of potential damage depends on winds, wind direction, the type of surrounding vegetation and topography (Forman and Alexander 1998). Chemicals used for road maintenance, particularly in areas with snowy or icy precipitation, can affect the composition of roadside vegetation (Forman and Alexander 1998). We were unable to find any data relating these potential effects directly to impacts on sage-grouse population parameters.

In a study on the Pinedale Anticline in Wyoming, sage-grouse hens that bred on leks within 3 km (1.9 mi) of roads associated with oil and gas development traveled twice as far to nest as did hens bred on leks greater than 3 km (1.9 mi) from roads. Nest initiation rates for hens bred on leks "close" to roads were also lower (50 vs. 65 percent) affecting population recruitment (33 vs. 44 percent) (Lyon 2000; Lyon and Anderson 2003). Lyon and Anderson (2003) suggested that roads may be the primary impact of oil and gas development to sage-grouse, due to their persistence and continued use even after drilling and production have ceased. Braun et al. (2002) suggested that daily vehicular traffic along road networks for oil wells can impact sage-grouse breeding activities based on lek abandonment patterns. In a study of 804 leks within 100 km (62.5 mi) of Interstate 80 in southern Wyoming and northeastern Utah, Connelly et al. (2004) found that there were no leks within 2 km (1.25 mi) of the interstate and only 9 leks were found between 2 and 4 km (1.25 and 2.5 mi) along this same highway. The number of active leks increased with increasing distance from the interstate. Lek persistence and activity relative to distance from the interstate were also measured. The distance of a lek from the interstate was a significant predictor of lek activity, with leks further from the interstate more likely to be active. An analysis of long-term changes in populations between 1970 and 2003 showed that leks closest to the interstate declined at a greater rate than those further away (Connelly et al. 2004). What is not clear from these studies is what specific factor relative to roads (e.g., noise, changes in vegetation, etc.) sage-grouse are responding, and Connelly et al. (2004) caution that they have not included other potential sources of indirect disturbance (e.g., powerlines) in their analyses.

Aldridge et al. (2008, p. 992) did not find road density to be an important factor affecting sage-grouse persistence or rangewide patterns in sage-grouse extirpation. However, the authors did not consider the intensity of human use of roads in their modeling efforts. They also indicated that their analyses may have been influences by inaccuracies in spatial road data sets, particularly for secondary roads (Aldridge et al. 2008, p. 992). Accurate assessments of road impacts are to sage-grouse populations are more relevant to local populations and not rangewide analyses (Aldridge et al. 2008, p. 992).

Railroads presumably have the same potential impacts to sage-grouse as do roads since they create linear corridors within sagebrush habitats. Railways were primarily responsible for the initial spread of cheatgrass in the intermountain region (Connelly et al. 2004). Cheatgrass, an exotic species that is unsuitable as sage-grouse habitat, readily invaded the disturbed soils adjacent to railroads, being distributed by trains and the cattle they transported. Fires created by trains facilitated the spread of cheatgrass into adjacent areas. Railroads cover 137 km^2 (53 mi^2) of the sage-grouse in Connelly et al.'s (2004) assessment area, but are estimated to influence an area of 183,915 km^2 (71,000 mi^2), assuming a 3 km (1.9 mi) zone of influence (9 percent of their assessment area). Avian collisions with trains occur, although no estimates of mortality rates are documented in the literature (Erickson et al. 2001).

Habitat—Urbanization

Low densities of indigenous peoples have been present for more than 12,000 years in the historical range of sage-grouse. By 1900, Connelly et al. (2004) reported that less than 1 person/km^2 resided in 51 percent of the 325 counties within their assessment area, and densities greater than 10 persons/km^2 occurred in 4 percent of the counties. By 2000, counties with less than 1 person/km^2 occurred in 31 percent of the 325 counties and densities greater than 10 persons/km^2 occurred in 22 percent of the counties (Connelly et al. 2004). Today, the dominant urban areas are located in the Bear River Valley of Utah, the portion of Bonneville Basin southeast of the Great Salt Lake, the Snake River Valley of southern Idaho, and in the Columbia River Valley of Washington (Rand McNally Road Atlas 2003, Connelly et al. 2004).

Western states accounted for 50 percent of all population growth in the United States from 1999-2000 (Anderson and Woosley 2005, p. 6). This growth has led to increases in both urban/suburban and rural development. Urban development has eliminated some sage-grouse habitat (Braun 1998). Interrelated effects from urban/suburban development include construction of associated infrastructure (e.g., roads, powerlines, and pipelines) and predation threats from the introduction of domestic pets and increases in predators subsidized by human activities. In particular, municipal solid waste landfills (landfills) and roads have been shown to contribute to increases in common raven populations (Knight et al. 1993, Restani et al. 2001, Webb et al. 2004). Ravens are known to be an important predator on sage-grouse nests and have been considered a restraint on sage-grouse population growth in some locations (Batterson and Morse 1948, Autenrieth 1981, Altstatt 1995). Landfills (and roads) are found in every State and a number of these are located within or adjacent to sage-grouse habitat.

Recent changes in demographic and economic trends have resulted in greater than 60 percent of the Rocky Mountain West's counties experiencing rural sprawl where rural areas are outpacing urban areas in growth (Theobald 2003, p.3). In some Colorado counties, up to 50 percent of sage-grouse habitat is under rural subdivision development, and it is estimated that 3 to 5 percent of all sage-grouse historical habitat in Colorado has already been converted into urban areas (Braun 1998). We are unaware of similar estimates for other States within the range of the greater sage-grouse, and therefore cannot determine the effects of this factor on a rangewide basis. Rural development has increasingly taken the form of low-density (aprx. 6-25 homes/km^2) home development or exurban growth (Hansen et al. 2005, p. 1894). Between 1990 and 2000, Theobald (2001, p. 553) reported 120,000 km^2 of land were developed at exurban densities. This value, however, includes development nationwide and we are unable to report values specifically for sagebrush habitats. Similar to higher density urbanization, exurban development has the potential to negatively affect sage-grouse populations through direct habitat loss, increased infrastruction, and increased predation. Maestas et al. (2003, p. 1430) found lower native species richness (birds, plants) and higher non-native species richness (domestic pets, plants) at exurban sites as opposed to sites used for ranching or designated as preserves in Colorado. Hansen et al. (2005, p. 1896) found that species richness was correlated with the age of the developed area, with bird species richness continuing to decline more than 60 years after development.

In modeling sage-grouse persistence, Aldridge et al. (2008, pp. 991-992) found that the density of humans in 1950 was the best predictor of sage-grouse extirpation among the human population metrics considered (including increasing human population growth). Sage-grouse extirpation was more likely in areas having a moderate human population density of at least four people per km^2. Increasing human populations were not a good predictor of sage-grouse persistence most likely because much of the growth occurred in areas that are already no longer suitable for sage-grouse. Aldridge et al. (2008, p. 990) also reported that based on their models sage-grouse require a minimum of 25 percent sagebrush for persistence in an area. A high probability of persistence required 65 percent sagebrush or more. Therefore, human population growth that results in exurban development in sagebrush habitats may reduce the likelihood of sage-grouse persistence in the area.

Given the current demographic and economic trends in the Rocky Mountain West, we have no reason to believe that rates of urbanization and exurbanization will not continue increasing, resulting in further habitat fragmentation and degradation. Currently, however, we are unable to quantify the extent of that habitat loss and its potentially negative effect on long-term greater sage-grouse persistence.

UTILIZATION OF SAGE-GROUSE IN COMMERCIAL, RECREATIONAL, RELIGIOUS, SCIENTIFIC, OR EDUCATIONAL ACTIVITIES

Commercial Activity

Although commercial hunting of greater sage-grouse occurred in the late 1800s and early 1900s (Patterson 1952, pp. 30-32; Autenrieth 1981, pp. 3-11) there has been no commercial harvest of the species for many decades. Consequently, commercial utilization of the species is not occurring and does not influence any greater sage-grouse populations.

Recreational Activity

In this section we review and evaluate information pertaining to sport hunting as well as non-consumptive activities (e.g. bird watching) conducted specifically for greater sage-grouse. The effects of other types of recreational activities (e.g. off-highway vehicle activity) on the species and its habitat are discussed under miscellaneous concerns.

Sport Hunting: Sport hunting is a recreational activity that involves the direct utilization of greater-sage grouse. Historically, the greater sage-grouse was heavily exploited by commercial and sport hunting in the late 1800s and early 1900s (Patterson 1952, pp. 30-32; Autenrieth 1981, pp. 3-11). Hornaday (1916, pp. 179-221) and others alerted the public to the risk of extinction to the species as a result of this overharvest. In response, many States closed sage-grouse hunting seasons by the 1930s (Patterson 1952, pp.30-33; Autenrieth 1981, p. 10). The impacts of hunting on greater sage-grouse during those historical decades may have been exacerbated by impacts from human expansion into sagebrush-steppe habitats (Girard 1937, p. 1).

With the increase of sage-grouse populations by the 1950s, limited hunting seasons were again allowed in most of the species range (Patterson 1952, p. 242; Autenrieth 1981, p.11). Currently, greater sage-grouse are legally sport-hunted in 10 of 11 States where they occur (Connelly et al. 2004, p. 6-3). The hunting season for sage-grouse in Washington was closed in 1988 and the species was added to the state's list of threatened species in 1998 (Stinson et al. 2004, p. 1). In Canada sage-grouse are designated as an endangered species and hunting is not allowed (Connelly et al. 2004, p. 6-3).

Central to the idea of a sustainable harvest are the concepts of compensatory and additive mortality (Connelly 2005, p. 7). The concept of compensatory mortality is that for wildlife populations subject to density dependent mortality, various mortality factors (e.g. starvation, disease, predation) frequently are compensatory rather than additive in terms of their effect on the population. For example, if a certain percentage of a population is taken by predation a lower percentage will die of starvation than would have occurred in the absence of predation (Robinson and Bolen 1984, p. 255). With regard to hunting, the concept of compensatory morality has been considered to characterize situations when there is relatively stable annual mortality regardless of which factors are causing mortality, and thus elimination of hunting will result in increased mortality from other causes such as predation or disease (Dasman 1964 as cited in Connelly et al 2005, p. 660). In contrast, hunting mortality that is additional to natural mortality is termed additive, i.e. the hunting mortality adds to the natural mortality, such that the total mortality is greater than if hunting did not occur (Connelly et al. 2005, p. 660). Thus if hunting is a form of compensatory mortality it will not contribute to a population decline, whereas if hunting is a form of additive mortality it will affect population dynamics potentially resulting in a population decline. Despite the fact that the validity or ubiquity of compensatory mortality has not been rigorously tested (i.e., randomized experimental treatments, replicated studies), it has become a central theme in upland gamebird management (Romesburg 1981, pp. 303-304; Applegate 2004, p.105; Connelly 2005, p. 8). Based on the assumption that hunting mortality is compensatory, game managers typically attempt to set wildlife harvest levels below a threshold that is related to natural overwinter mortality. Autheirth (1981, p. 77) suggested sage-grouse could sustain harvest rates of up to 30 percent annually. Braun (1987, p. 139) suggested a rate of 20-25 percent was sustainable. State wildlife agencies currently attempt to keep harvest levels below 5-10 percent of the population, based on recommendations taken from Connelly et al. (2000a, p. 976), who stated that most greater sage-grouse populations could sustain hunting if the seasons are carefully regulated to keep total mortality within sustainable levels. However, similar to previous suggested harvest rates, this has not been experimentally tested with regard to it impacts on sage-grouse populations.

Although hunting has long been thought to be a form of compensatory mortality for upland game birds, questions have been raised in recent years about whether that actually is the case. This information is summarized by Connelly et al. 2005 (pp. 660, 663) who cite studies suggesting that hunting of upland game, including the greater sage-grouse, is often not compensatory. Several studies have sought to determine whether hunting mortality in sage-grouse is compensatory or additive, primarily by comparing lek count data to known harvest rates. Braun (1987, p. 139) found that harvest levels of 7-11 percent had no affect on subsequent spring breeding populations based on lek counts in North Park, Colorado, and concluded harvest at that level was compensatory. Johnson and Braun (1999, p. 83) determined that overwinter mortality correlated with harvest intensity in North Park, Colorado, and hypothesized that hunting mortalities may be additive. Crawford (1982, p. 376) found no relationship between harvest rates and subsequent spring populations in Oregon and suggested that hunting mortality was compensatory. Crawford and Lutz (1985, p. 72) found that harvests of >5,000 birds negatively affected sage-grouse populations in Oregon, but that the impact was short-lived. Connelly et al. (2003, pp. 256-257) evaluated data for monitored lek routes in areas experiencing different levels of harvest (no harvest, 1-bird season, 2-bird season) and found that populations with no hunting season had faster rates of population increase than populations with a light to modest harvest. The effect was particularly pronounced in xeric habitats near human populations, which suggests that the impact of hunting on sage-grouse to some extent depends on habitat quality. In Long Valley, California, data collected on sage-grouse population trends following a 3-year period during the mid-1980's when hunting was closed indicate that hunting mortality was additive, suppressing population size well below the apparent carrying capacity (Gardner 2008). It may be that in natural populations of wildlife, hunting mortality may fall between the two extremes of being totally additive or totally compensatory (Robertson and Rosenberg 1988 as cited in Connelly et al., 2005, p. 663). Overall, there is greater recognition that the effects of hunting can vary depending on population and habitat characteristics, and that successful harvest management programs must consider a species' reproductive characteristics and the quality of habitat occupied by a population (Connelly et al. 2005, p. 663).

Sage-grouse hunting is regulated by State wildlife agencies. Hunting seasons are reviewed annually, and States change harvest management based on estimates for spring production and population size (e.g. Bohne 2003, pp.1-10). Harvest, however, is carried out on fall populations of sage-grouse and currently there is no reliable method for obtaining estimates of fall population size (Connelly et al. 2004, p. 9-6). Instead lek counts conducted in the spring are used as a surrogate for fall population size. In reality, however, by fall populations are already reduced from spring estimates as some natural mortality inevitably has occurred in the interim (Kokko 2001, p. 164). This discrepancy between spring and fall population size estimates plays a role in determining whether harvest will be within the recommended level of <5-10 percent of the fall population. For example, hen mortality in Montana increased from the typical level of 1-5 percent to 16 percent during July/August in a year (2003) with West Nile virus mortality (Moynahan 2006, p.1535). In South Dakota, summer mortality from West Nile was estimated to be between 21-63 percent of the population (Kaczor 2008, p.72).

Even if the harvest is at the recommended level of <5-10 percent of a population, the impact of harvest on females needs to be taken into consideration, as female survivorship is a key element of population productivity. There is some evidence that harvest might affect females and males differently. Connelly et al. (2000b, p.228-229) found that in Idaho 42 percent of female mortality was attributable to hunting while for males the number was 15 percent. Patterson (1952, p. 245) found females accounted for 60 percent (1950) and 63 percent (1951) of total hunting mortalities. Because sage-grouse are relatively long lived, have moderate reproductive rates, and are highly polygynous, their populations are likely to be especially sensitive to adult female survival (Schroeder 1999, p.2, 13; Saether and Bakke 2000, p. 652; Connelly 2005, p.9).

All States with hunting seasons have changed limits and season dates to more evenly distribute hunting mortality across the entire population structure of greater sage-grouse by harvesting birds after females have left their broods (Bohne 2003, p. 5).

However, despite increasingly later hunting seasons, hens in Wyoming continue to comprise the majority of the harvest in all years (WGFD 2004 Job Completion Report (JCR), p. 4; WGFD 2006 JCR p. 7). Of 2813 harvested wings collected at various locations in Nevada in 2006, on average 59 percent were adult and juvenile females, and at local levels females made up between 45-94 percent of the wing data (NDOW web page). These results could mean that females are more susceptible to hunting mortality or it may simply be a reflection of a female skewed sex ratio in adult birds. Male sage-grouse in general experience lower survival rates than females, and the varying degrees of female skewed sex ratios recorded for sage-grouse are thought to be as a result of this differential survival (Swenson 1986, p. 16; CO GSG Conservation Plan, p. 54). The potential for negative effects on populations by harvesting reproductive females has long been recognized by upland game managers (e.g. hunting of female ring-necked pheasants is prohibited in most states). For sage-grouse we note also that yearling hens have less reproductive potential than adults (Dalke et al. 1963, p. 839; Moynahan 2006, p. 1537), and high female mortality has the potential to result in negative lag effects as future populations become overrepresented by yearling females (Moynahan 2006, p. 1537).

Harvest management levels that are based on the concept of compensatory mortality assume that overwinter mortality, which is typically low in sage-grouse (~2 percent, Connelly et al. 2000b, p. 229), is density dependent. However, due to West Nile virus, sage-grouse population dynamics may be increasingly affected by mortality that is density independent. Further, there is increasing concern regarding wide-spread habitat degradation and fragmentation from various sources, such as development, fire, and the spread of noxious weeds, all of which can reduce the amount of suitable habitat and thus reduce sage-grouse populations. State management agencies have become increasingly responsive to these concerns. All of the States where hunting greater sage-grouse is legal, except Montana, now manage harvests on a regional scale rather than applying state-wide limits, and emergency closures have been utilized for some populations in decline (Connelly 2005, p. 9). North Dakota, for example, closed the 2008 hunting season due to record low lek attendance likely due to West Nile virus (Robinson 2008). Hunting on the Duck Valley Indian Reservation (Idaho/Nevada) has been closed since 2006 due to West Nile virus (Dick 2008; Gossett 2008). Hunting on Owyhee County, Nevada was closed in 2006 and again in 2008 as a result of West Nile virus. As mentioned above, later harvest seasons have been implemented by all states in an effort to reduce hunting pressure on females (Bohne 2003, p. 4). Bag limits and season lengths are relatively conservative compared to the past (Connelly 2005, p.9; Gardner 2008). Currently, opening dates range from September 1 to October 5, with season lengths of 2 to 62 days for gun/bow hunters. Daily bag limits range from 1 to 2 birds with possession limits from 1 to 4 birds.

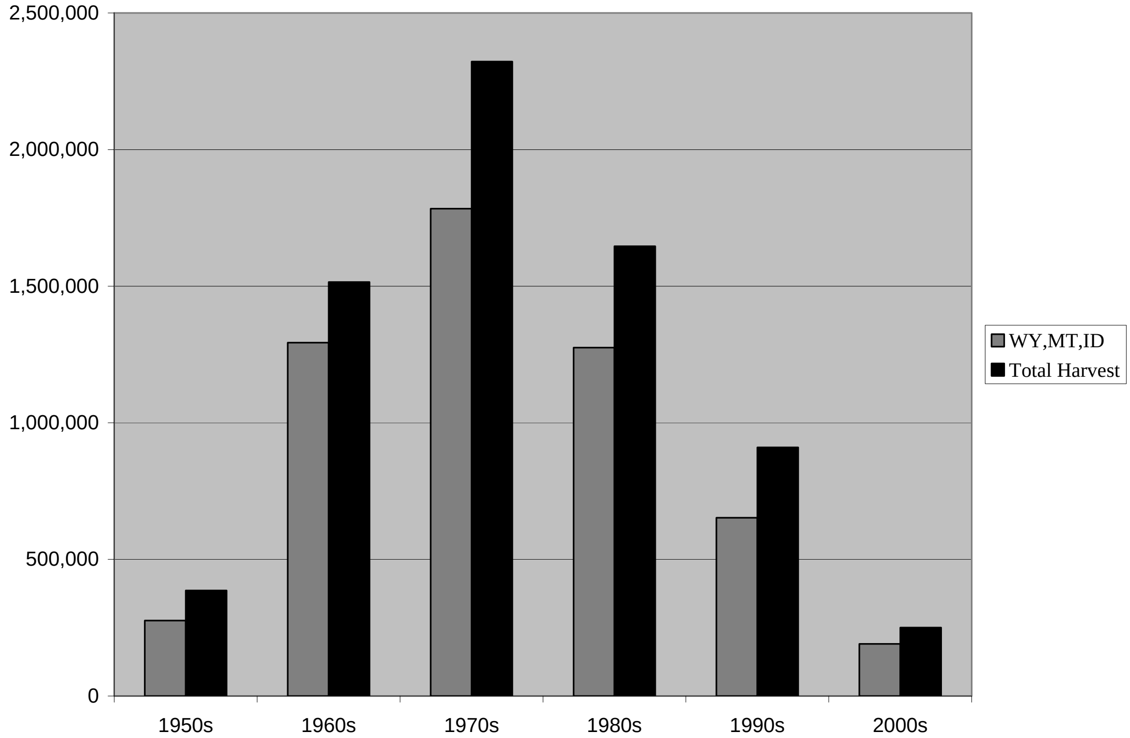
Harvest levels have varied considerably since the 1950's, and in recent years have been much lower than in past decades. We lack data gun/bow harvest data for a few states in earlier decades. Based on the data we do have, Table 9 presents the range in annual numbers of greater sage-grouse harvested in each decade since the 1950's; we note that due to a few states for which we have no data, these are minimum numbers, but nevertheless provide some useful information.

Table 9: Range in the number of greater sage-grouse harvested by gun/bow, by decade; due to a few States for which data are missing, the numbers are minimums.

DECADE	Lowest Number (Year)	Highest Number (Year)
1950's	2,941 (1950)	115,466 (1958)
1960's	61,929 (1960)	265,589 (1969)
1970's	196,874 (1977)	323,555 (1979)
1980's	105,689 (1985)	237,452 (1980)
1990's	48,044 (1997)	166,034 (1990)
2000 - 2007	20,680 (2003)	37,597 (2005)

Based on our review of harvest estimates provided by the States, we note the following points in relation to each decade. During the 1950's the reported harvest increased substantially in the second half of the decade, but this is in part a reflection of having no harvest data for Wyoming until 1957. In the 1960's the reported annual harvest increased substantially after 1961, but is in part due to lack of information for Colorado, Montana, and Nevada; harvest exceeded 120,000 annually for 7 years in that decade. In the 1970's the harvest was above 200,000 in 9 of 10 years. During the 1980's harvest exceeded 130,000 in 9 of 10 years. The harvest was above 100,000 annually during the early 1990's but dropped substantially in the last half of the decade. From 2000 through 2007, annual harvests have been much lower than in the prior decades.

Figure 10: Total Greater sage-grouse harvest by decade for available state-wide harvest estimates and combined harvest estimates from WY, MT, and ID only (**1950s** - no data for CA, CO, MT, NV and missing data for WY, ID, and SD; **1960s** - no data for CA, ND, SD, and missing data for NV, CO; **1970s** - no data for CA, ND; **1980s-2007** data set is complete).



From the 1950's to the present, harvests were highest in the 30 years spanning the 1960's through the 1980's (Fig 10). The harvest information by state for those 3 decades shows that three states – Wyoming, Idaho, and Montana – accounted for at least 75 percent of the harvest each year, and sometimes more than 85 percent. Wyoming had the highest harvest of greater sage-grouse in most years, ranging from a low of 40,886 (1970) to a high of 93,208 (1979), and exceeding 50,000 in 21 years. Idaho generally reported the second highest annual harvest, ranging from a low of 15,200 (1960) to a high of 92,600 (1979), and exceeding 50,000 in 15 years. The harvest in Montana exceeded that of Idaho during 5 years from 1962 (the first year for which we have harvest information for Montana) to 1966, and exceeded that of Wyoming during 4 years (1963-64, 1966, 1973). From 1962 through 1989, Montana's harvest ranged from a low of 10,791 (1985) to a high of 99,138 (1964), and exceeded 50,000 in 6 years.

Table 10 shows the annual gun/bow harvest and the percent of the total harvest by state for 2004-2007, the most recent years for which we have harvest data for each state where sage-grouse are legally hunted. Wyoming accounts for the largest percentage of the harvest with gun/bow hunting, with more than one-third of all such harvest in each year. Idaho accounted for one-quarter of the total in 2004, and for approximately one-third of the harvest in 2005 and 2006. In 2007, however, Idaho dropped to 18.5 percent, and the decrease there accounted for most of the overall harvest reduction reported in 2007. The reduction in Idaho was likely due to at least three factors 1) closures as a result of the Murphy Complex wildfire 2) season reduction in North Magic Valley, a planning area typically with one of the highest harvest rates, due to significant declines in spring lek attendance, and 3) one of the lowest levels of productivity (0.82 chicks/hen) in the previous six years. (ID LWG annual report 2007, pp. 7-9). Montana accounted for approximately 9 to 13 percent, and Nevada for roughly 9 to 18 percent.

Table 10: Total number and percent of greater sage-grouse reported taken through gun/bow harvest, 2004-2007, by State.

STATE	2004	2005	2006	2007
California	180 *0.1 percent*	152 *0.4 percent*	191 *0.5 percent*	47 *1.8 percent*
Colorado	1,731 *5.3 percent*	1,115 *3.2 percent*	745 *2.0 percent*	1,197 *4.5 percent*
Idaho	8,050 *24.6 percent*	10,537 *30.3 percent*	12,500 *33.2 percent*	4,935 *18.5 percent*
Montana	3,056 *9.4 percent*	3,515 *10.1 percent*	4,927 *13.1 percent*	3,116 *11.7* percent
Nevada	5,244	3,175	3,701	4,897

	16.1 percent	*9.1 percent*	*9.8 percent*	*18.4 percent*
North Dakota	7 *<0.1 percent*	14 *<0.1 percent*	8 *<0.1 percent*	21 *<0.1 percent*
Oregon	1,228 *3.8 percent*	1,277 *3.7 percent*	1,092 *2.9 percent*	766 *2.9 percent*
South Dakota	25 *<0.1 percent*	26 *<0.1 percent*	15 *<0.1 percent*	10 *<0.1 percent*
Utah	1,361 *4.2 percent*	1,744 *5.0 percent*	1,498 *4.0 percent*	1,255 *4.7 percent*
Wyoming	11,783 *36.1 percent*	13,167 *37.9 percent*	12,929 *34.4 percent*	10,378 *39.0 percent*
TOTALS	32,665	34,722	37,597	26,622

All 10 States that allow gun hunting of sage-grouse also allow falconers to hunt sage-grouse. Falconry season opening dates range from August 15 to November 1 and run for 60 to 214 days. Daily bag limits range from 1 to 3 birds and possession limits range from 1 to 6. Falconry seasons are considerably longer with in some cases larger bag limits than bow/gun season. However due to the low numbers of falconers and their dispersed activities levels of harvest through falconry are thought to be negligible (Apa 2008; Northrup 2008; Hemker 2008; Olsen 2008; Kanta 2008). Wyoming is one of the few states that collects falconry harvest data and reported a take of 180 sage-grouse by falconers in 2006-2007 season (WGFD 2007 annual report). In Oregon the take is probably less than 5 birds per year (Budeau 2008). In Idaho the 2005 estimated statewide falconry harvest was 77 birds and that number has likely remained relatively constant (Hemker 2008 email). We are not aware of any studies that have examined falconry take of greater sage-grouse in relation to population trends, but the amount of greater sage-grouse mortality associated with falcon sport hunting appears to be negligible.

We surveyed the State fish and wildlife agencies within the range of greater sage-grouse to determine what information they had on illegal harvest (poaching) of the species. Nevada and Utah indicated they were aware of citations being issued for sage-grouse poaching, but that it was rare (Espinosa 2008, Olsen 2008). Sage grouse wings are infrequently discovered in wing barrel collection sites during forest grouse hunts in Washington, but such take is considered a result of hunter misidentification rather than deliberate poaching (Schroeder 2008). None of the remaining States had any quantitative data on the level of poaching in their States. Based on these results, illegal harvest of greater sage-grouse poaching appears to occur at low levels. We are not aware of any studies or other data that demonstrate that poaching has contributed to sage-grouse population declines.

In summary, no studies have demonstrated that regulated hunting is a primary cause of the decline in the numbers of greater sage-grouse observed over a period of years in the past (Connelly et al. 2004, p. 9-6). However, there remains uncertainty, due in large part to a lack of experimental evidence, regarding whether hunting has been a contributing factor to those declines. Significant habitat loss and fragmentation have occurred during the past several decades and there is evidence that the sustainability of harvest levels depends to a large extent upon the quality of habitat (Connelly 2005, p. 9; Connelly et al. 2004, p. 9-3; Connelly et al. 2003, pp. 256-257). Populations in Washington and Canada now prohibit sage-grouse harvest yet populations have not recovered. This fact is frequently used as evidence that hunting has played little or no role in sage-grouse declines because habitat loss is clearly the limiting feature (Connelly et al. 2004, p. 9-6). Recognizing that habitat loss is a limiting factor for those populations, however, is not conclusive evidence that hunting played no role in declines.

Non-consumptive Recreational Activity: Greater sage-grouse are subject to a variety of non-consumptive recreational uses such as bird watching or tour groups visiting leks, general wildlife viewing, and photography. Daily human disturbances on sage-grouse leks could cause a reduction in mating, and some reduction in total production (Call and Maser 1985, p. 19). Wyoming Game and Fish Department provides the public directions to 16 leks and guidelines to minimize viewing disturbance. Leks included in the brochure are close to roads and already subject to some level of disturbance (Christiansen 2008). Colorado and Montana have some sites with viewing trailers for the public (Apa 2008; Northrup 2008).

Overall, a relatively small number of leks in each state receive regular viewing use visitation by humans during the strutting season and most states report no known impacts from this use (Apa 2008; Christiansen 2008; Gardner 2008; Northrup, Montana 2008). Only Colorado has collected data regarding the effects of non-consumptive use; their data suggest that controlled lek visitation has not impacted greater sage-grouse (Apa 2008). Oregon, however, reported anecdotal evidence of negative impacts of unregulated lek viewing to individual leks near urban areas and subject to frequent disturbance from visitors (Hagen 2008). We were not able to locate any studies documenting how lek viewing, or other forms of non-consumptive recreational uses, of sage-grouse are related to sage-grouse population trends. Given the relatively small number of leks visited we have no reason to believe that this type of recreational activity is having a negative impact on local populations or contributing to declining population trends.

Religious Activity

Some Native American tribes harvest greater sage-grouse as part of their religious or ceremonial practices as well as for subsistence. Native American hunting occurs on the Wind River Indian Reservation (Wyoming), with about 20 males per year taken off of leks in the spring plus an average fall harvest of approximately 40 birds (Hnilicka 2008). The Shoshone-Bannock Tribe (Idaho) occasionally takes small numbers of birds in the spring, but no harvest figures have been reported for 2007 and 2008 (Christopherson 2008). The Shoshone-Paiute Tribe of the Duck Valley Indian Reservation (Idaho/Nevada) suspended hunting in 2006, 2007, and 2008 due to significant population declines resulting from a West Nile virus outbreak in the area (Dick 2008; Gossett 2008). Prior to 2006 the sage-grouse hunting season on the Duck Valley Indian Reservation ran from July 1 to November 30 with no bag or possession limits. Preliminary estimates showed that the harvest may have been as high as 25 percent of the population (Gossett 2008). Despite the hunting ban, populations have continued to decline on the reservation (Dick 2008, Gossett 2008). No harvest by Native Americans for subsistence or religious and ceremonial purposes occurs in South Dakota, North Dakota, Colorado, Washington, or Oregon (Apa 2008; Hagen 2008; Kanta 2008, Robinson 2008, Schroeder 2008).

Scientific and Educational Activity

Greater sage-grouse are the subject of many scientific research studies. We are of aware of 51 studies ongoing or completed during 2005-2008. Of the 11 western States where sage-grouse currently occur, all reported some type of field studies that included the capture, handling, and subsequent banding, or banding and radio-tagging of sage-grouse. In 2005, the overall mortality rate due to the capture, handling, and/or radio-tagging process was estimated at approximately 2.7 percent of the birds captured (68 mortalities of 2491 captured). A survey of state agencies, BLM, consulting companies, and graduate students involved in sage-grouse research indicates that there has been little change in direct handling mortality since then. We are not aware of any studies that document that this level of taking has affected any sage-grouse population trends.

Greater sage-grouse have been translocated in several States and the Province of British Columbia (Reese and Connelly 1997, p. 235). Reese and Connelly (1997, pp. 235-238) documented the translocation of over 7,200 birds between 1933 and 1990, and additional translocation efforts have taken place since 1990. Only 5 percent of the translocation efforts documented by Reese and Connelly (1997, p. 240) were considered to be successful in producing sustained, resident populations at the translocation sites. Since 2004, Oregon and Nevada have supplied the State of Washington with close to 100 greater sage-grouse to increase the genetic diversity of geographically isolated populations and to reestablish a historic population. One bird has died during transit and as expected natural mortality for translocated birds has been higher than resident populations (Schroeder 2008). In the case of the population augmentations, translocated birds have bred with resident birds. No information is available at this time regarding the success or effectiveness of the reintroduction. Given the low numbers of birds that have been used for translocation spread over many decades it is unlikely that the removals from source populations have contributed to greater sage-grouse declines, while the limited success of translocations has also likely had nominal impact on rangewide population trends.

We did not find any information regarding the direct use of greater sage-grouse for educational purposes.

Summary of Sage-grouse Utilization

Greater sage-grouse are not used for any commercial purpose. We have no evidence suggesting that gun/bow sport hunting has been a primary cause of observed rangewide declines of the greater sage-grouse, although negative impacts on local populations having been demonstrated. Harvest related to falconry is negligible. Take from poaching (illegal hunting) appears to occur at low levels in localized areas, and there is no evidence that it contributes to population declines. The information on non-consumptive recreational activities is limited to lek viewing, the extent of such activity is small, and there is no indication that it has a negative impact that contributes to population declines. Harvest by native tribes, and mortality that results from handling greater sage-grouse for scientific purposes appears to occur at low levels in localized areas and thus we do not consider these to be threat at either the rangewide or local population levels. We know of no utilization for educational purposes.

NATURAL ENEMIES

Natural Enemies—Disease

There have been few systematic surveys for parasites or infectious diseases of the greater sage-grouse, and therefore, their role in population declines is unknown for this species (Connelly et al. 2004). Some early studies have suggested that sage-grouse populations are adversely affected by parasitic infections (Batterson and Morse 1948). Parasites have also been implicated in sage-grouse mate selection, with potentially subsequent effects on the genetic diversity of this species (Boyce 1990; Deibert 1995), but Connelly et al. (2004) note that while these relationships may be important to the long-term ecology of greater sage-grouse, they have not been shown to be significant to the immediate status of populations. Connelly et al. (2004) have suggested that diseases and parasites may limit isolated sage-grouse populations. The potential effects of emerging diseases require additional study.

Sage-grouse are hosts to many parasites (Connelly et al. 2004; Thorne et al. 1982). Only the protozoan, *Eimeria* spp., which causes coccidiosis (Connelly et al. 2004), has proven to be fatal, but mortality is not 100 percent, and young birds that survive an initial infection typically do not succumb to subsequent infections (Thorne et al. 1982). Infections tend to be localized to specific geographic areas. Most cases of coccidiosis in greater sage-grouse have been found where large numbers of birds congregated, resulting in soil and water contamination by fecal material (Connelly et al. 2004). While the role of this parasite in population changes is unknown, Petersen (2004) hypothesized that coccidiosis could be limiting for local populations, as this parasite causes decreased growth and significant mortality in young birds, thereby potentially limiting recruitment. However, no cases of sage-grouse mortality resulting from coccidiosis have been documented since the early 1960s (Connelly et al. 2004).

Other parasites which have been documented in the greater sage-grouse include *Sarcosystis* spp (another form of coccidea), blood parasites (including avian malaria, *Leucocytozoon* spp., *Haemoproteus* spp., and *Trypanosoma avium*), *Tritrichomonas* simoni, tapeworms, gizzard worms (*Habronema* spp. and *Acuaria* spp.), cecal worms, and filarid nematodes (Thorne et al. 1982; Connelly et al. 2004; Petersen 2004). None of these parasites have been known to cause mortality in the greater sage-grouse. Sub-lethal effects of these parasitic infections on sage-grouse have never been studied.

Greater sage-grouse host many external parasites, including lice, ticks, and dipterans (midges, flies, mosquitoes, and keds) (Connelly et al. 2004). Most ectoparasites do not produce disease, but can serve as disease vectors or cause mechanical injury and irritation (Thorne et al. 1982). Many biologists contend that ectoparasites can be detrimental to their hosts, particularly when the bird is stressed by inadequate habitat or nutritional conditions (Petersen 2004). Some studies have suggested that lice infestations can affect sage-grouse mate selection (Boyce 1990; Spurrier et al. 1991; Deibert 1995), but population impacts are not known (Connelly et al. 2004).

Greater sage-grouse are also subject to a variety of bacterial, fungal, and viral pathogens. The bacteria *Salmonella* spp. has caused mortality in the greater sage-grouse; the bacteria apparently contracted through of exposure to contaminated water supplies around livestock stock tanks (Connelly et al. 2004). Other bacteria found in sage-grouse include *Escherichia coli*, botulism (*Clostridium* spp.), avian tuberculosis (*Mycobacterium avium*), and avian cholera (*Pasteurella multocida*). These bacteria have never been identified as a cause of mortality in greater sage-grouse and the risk of exposure and hence, population effects, is low (Connelly et al. 2004). One case of aspergillosis, a fungal disease, has been documented in sage-grouse, but there is no evidence to suggest this fungus plays a role in limiting greater sage-grouse populations (Connelly et al. 2004; Petersen 2004).

Viral diseases could cause serious diseases in grouse species and potentially influence population dynamics (Petersen 2004). However, prior to 2003 only avian infectious bronchitis (caused by a coronavirus) had been identified in the greater sage-grouse. No clinical signs of the disease were observed.

West Nile Virus: West Nile virus (WNv) was introduced into the northeastern United States in 1999 and has subsequently spread across North America (Marra et al.

2004, p.394). This virus is thought to have caused millions of wild bird deaths since its introduction (McLean 2006, pp. 47-55), but most WNV mortality goes unnoticed or unreported (Ward et al. 2006; p. 101). The virus persists largely within a mosquito-bird-mosquito infection cycle (McLean 2006; p. 45). However, direct bird to bird transmission of the virus has been documented in several species (McLean 2006; pp. 54 and 59) including the greater sage-grouse (70 FR 2270). The frequency of direct transmission has not been determined (McLean 2006, p. 54).

Impacts of WNv on the bird host varies by species with some species being relatively unaffected (e.g. mourning dove (*Zenaida macroura*)) and others experiencing mortality rates of up to 68 percent (e.g. juvenile American white pelican (*Pelecanus erythrorhynchos)*) (Kilpatrick et al. 2007, p.1129; Sovada et al. 2008, p. 1027 and references therein). Greater sage-grouse are considered to have a high susceptibility to WNv, with resultant high levels of mortality (McLean 2006, p. 54; and discussion below).

In sagebrush habitats, WNv transmission is primarily regulated by environmental factors, including temperature, precipitation and distribution of anthropogenic water sources that support the mosquito vectors (Reisen et al. 2006, p. 309). Cold ambient temperatures preclude mosquito activity and virus amplification, so transmission to and in sage-grouse is limited to the summer (mid-May to mid-September) (Naugle et al. 2005, p. 620; Zou et al. 2007, p. 4). Documented WNv-related mortality in sage–grouse has been limited to these months, with a peak in July and August (Walker et al. 2007a; p.

693). Reduced and delayed WNv transmission in sage-grouse has occurred in years with lower summer temperatures (Naugle et al. 2005, p. 621; Walker et al. 2007a, p. 694). In other ecosystems, high temperatures associated with drought conditions increase WNv transmission by allowing for more rapid larval mosquito development and shorter virus incubation periods (Shaman et al. 2005, p.134). Greater sage-grouse congregate in mesic habitats in the mid-late summer (Connelly et al. 2000, p. 971) thereby increasing the risk of exposure to mosquitoes. If WNv outbreaks coincide with drought conditions that aggregate birds in habitat near water sources (due to the greater availability of suitable cover and food resources for greater-sage grouse), the risk of exposure to WNv will be elevated (Naugle et al. 2004). In greater sage-grouse, mortality from WNv occurs at a time of year when survival is otherwise typically high for adult females (Schroeder et al. 1999, p.14; Aldridge and Brigham 2003, p. 30), thus potentially making these deaths additive to other mortality sources and reducing average annual survival (Naugle et al. 2005, p. 621). WNv has been identified as a source of additive mortality in American white pelicans in the northern plains breeding colonies (Montana, North Dakota and South Dakota), and its continued impact has the potential to severely impact the entire pelican population (Sovada et al. 2008, p. 1030).

WNv was first detected in 2003 as a causative agent in greater sage-grouse mortalities in Wyoming. Data from four studies in the eastern half of the sage-grouse range (Alberta, Montana, Wyoming) showed survival in these populations declined 25 percent in July and August as a result of the WNv infection (Naugle et al. 2004, p. 711). Populations of grouse that were not affected by WNv showed no similar decline.

Additionally, individual sage-grouse in exposed populations were 3.4 times more likely to die during July and August, the “peak” of WNv occurrence, than birds in non-exposed populations (Connelly et al. 2004, p. 10-9; Naugle et al. 2004, p. 711). Subsequent declines in both male and female lek attendance in infected areas in 2004 compared with years before WNv was detected in this area suggest outbreaks could contribute to local population extirpation (Walker et al. 2004, p. 4). Lek surveys in 2004, however, indicated that regional sage-grouse populations did not decline, suggesting that the initial effects of WNv were localized (Wyoming Game and Fish Department, unpublished data, 2004). Eight sage-grouse deaths resulting from WNv were identified in 2004, four from the Powder River Basin area of northeastern Wyoming and southeastern Montana, one from the northwestern Colorado, near the town of Yampa and three in California (Walker et al. 2007b). Survival rates in July and September of that year were consistently lower in areas with confirmed WNv mortalities than those without (avg. 0.86 and 0.96, respectively; Naugle et al. 2005). There were no comprehensive efforts to track sage-grouse mortalities outside of these areas, so the actual distribution and extent of WNv in sage-grouse in 2004 is unknown (70 FR 2270).

As of December, 2007 WNv has been detected in humans, horses, and other species throughout the entire range of greater sage-grouse (Kilpatrick et al. 2007). Greater sage-grouse deaths resulting from this virus have been detected in 10 states and 1 province, involving Management Zones I, II, III, IV, V and VII. To date, no sage-grouse mortality in Washington (Management Zone 6) or Saskatchewan (part of Management Zone 1) have been detected. WNv has been detected in other species within the range of greater sage-grouse in Washington (http://diseasemaps.usgs.gov/wnv_wa_bird.html). Little information regarding outbreaks has been reported to date in 2008, although mortalities from the disease were documented in Wyoming (Wright 2008).

Impact on local populations and mortality rates: Several studies have examined the impact of WNv on local sage-grouse populations. Naugle et al. (2005; p. 617) reported a 25 percent decline in the survival of four greater sage-grouse populations in Alberta, Montana, and Wyoming. One outbreak near Spotted Horse, Wyoming in 2003 was associated with the subsequent extirpation of the local breeding population, with five leks affected by the disease becoming inactive within 2 years (Wyoming Game and Fish Department data). Also, in 2004, late summer survival rates were consistently lower at four sites across the species' range with confirmed WNv mortalities than at eight sites without (Naugle et al. 2005).

Mortality rates from WNv in a 50,000 km^2 area of northeastern Wyoming and southeastern Montana were between 2.4 (estimated minimum) and 28.9 percent (estimated maximum) in 2005 (Walker et al., 2007a; p. 693). In 2006, mortality rates in South Dakota among radio-marked juvenile sage-grouse ranged between 6.5 and 71 percent (Kaczor 2008, p. 63). Large sage-grouse mortality events were reported in the Jordan Valley and near Burns, Oregon (> 60 birds), and in several areas of Idaho and along the Idaho-Nevada border (> 55 birds) (U.S. Geological Survey 2006). While most of the carcasses had decomposed and were not testable, results for the few that were tested showed that they died from WNv.

Juvenile mortality rates in South Dakota in 2007 ranged from 20.8 (minimum estimate) to 62.5 percent (maximum estimate) (Kaczor 2008, p. 63), reducing recruitment the subsequent spring by 2 to 4 percent (Kaczor 2008, p. 65). A 52 percent decline in the number of males attending leks in North Dakota between 2007 and 2008 were also associated with WNv mortality in 2007 that prompted the state wildlife agency to close the hunting season in 2008 (www.gf.nd.gov/multimedia/news/2008/04/080413.html). The Duck Valley Indian Reservation along the border of Nevada and Idaho closed their hunting season in 2006 due to population declines resulting from WNv (Gossett 2008). WNv is still present in that area, with continued population declines (50.3 percent of average males per lek from 2005 to 2008) (Dick, 2008, p. 2), and the hunting season remains closed. The hunting season also remains closed in adjacent Owyhee County, Idaho for the same reason.

Surviving infection: In 2005, we reported that there was little evidence that greater sage-grouse can survive a WNv infection (70 FR 2270). This was based on the lack of sage-grouse found to have antibodies to the virus (as determined by serum samples) and from laboratory studies in which all sage-grouse exposed to the virus, at varying doses, died within 8 days (70 FR 2270). These data suggested that sage-grouse do not develop a resistance to the disease, and death is certain once an individual is exposed. However, six of 58 females (10.3 percent) birds captured in the spring of 2005 in northeastern Wyoming and southeastern Montana were seropositive for neutralizing antibodies, which suggests they were exposed to the virus the previous fall and survived an infection. Additional, but significantly fewer (2 of 109, or 1.8 percent) seropositive females were found in the spring of 2006 (Walker et al. 2007a, p. 693). The duration of immunity conferred by surviving an infection is unknown (Walker 2008, p. 64). It is also unclear whether sage-grouse have sub-lethal or residual effects resulting from a WNv infection, such as reduced productivity or overwinter survival (Walker et al., 2007a, p. 694). However, other bird species infected with WNv have been documented to suffer from chronic symptoms, including reduced mobility, weakness, disorientation, lack of vigilance, etc. (Nemeth et al. 2006, p. 253; Marra et al. 2004, p. 397), all of which may affect survival and/or reproduction. Reduced productivity in American white pelicans has been attributed to WNv (via reduced recruitment) (Sovada et al. 2008; p.1030).

Modeling: Walker (2008 pp. 161-216) modeled variability in greater sage-grouse population growth for the next 20 years under three WNv impact scenarios. These scenarios included: (1) no mortalities from WNv, (2) WNv- related mortality based on rates of observed infection and mortality rate data from 2003-2007, and (3) WNv-related mortality with increasing resistance to the disease over time. The addition of WNv-related mortality (scenario 2) resulted in a reduction of 9 to 12 percent population growth. The proportion of resistant individuals in the population increased marginally over the 20-year projection periods, from 4 to 15 percent under the increasing resistance scenario (scenario 3). While this increase in the proportion of resistant individuals did reduce the projected WNv rates, the author cautions that the presence of neutralizing antibodies in the live birds does not always indicate that these birds are actually resistant to infection and disease (Walker 2008). Additional models predicting the prevalence of WNv suggest that new sources of anthropogenic surface waters (e.g. coal-bed methane discharge ponds), increasing ambient temperatures, and a mosquito parasite that reduces the length of time the virus is present in the vector before the mosquito can spread the virus all suggest the impacts of this disease are likely increase (Miller 2008). However, these models are still being developed, so the final results are unknown.

Water sources: Human-created water sources in sage-grouse habitat known to support breeding mosquitoes that transmit WNv include overflowing stock tanks, stock ponds, irrigated agricultural fields and cold-bed natural gas discharge ponds (Zou et al. 2006, p. 1035). From 1999 through 2004, potential mosquito habitats in the Powder River Basin of Wyoming and Montana increased 75 percent (619 ha to 1084.5 ha) primarily due to the increase of small coal-bed natural gas water discharge ponds (Zou et al. 2006, p. 1034). Additionally, water developments installed in arid sagebrush landscapes to benefit wildlife continue to be common management practices. Several scientists have expressed concern regarding the potential for exacerbating WNv persistence and spread due to the proliferation of surface water features (e.g. Friend et al., 2001, p. 298; Walker et al. 2007a, p. 695; Zou et al., 2006, p.1040). Walker et al. (2007a; p. 694) concluded that impacts from WNv will depend less on resistance to the disease than on temperatures and changes in vector distribution. Zou et al. (2006, p. 1040) cautioned that the continuing development of coal-bed natural gas facilities in Wyoming and Montana contributes to maintaining, and possibly increasing WNv on that landscape through the maintenance and proliferation of surface water.

Long-term response of sage-grouse populations to WNv infections will vary depending on factors that influence exposure and susceptibility, such as temperature, land uses, sage-grouse population size, etc.) (Walker 2008, p. 65). Small, isolated or genetically limited populations are at higher risk as an infection may reduce population size below a threshold where recovery is no longer possible (Naugle 2008). Larger populations may be able to absorb impacts resulting from WNv as long as the quality and extent of available habitat supports positive population grown (Naugle 2008). However impacts from this disease may act synergistically with other stressors resulting in reduction of population size, bird distribution, or persistence (Walker et al. 2007b, p. 2652). WNv persists on the landscape after it first occurs as an epizootic, suggesting this virus will remain a long-term issue in affected areas (McLean 2006, p. 50).

Pro-active measures to reduce the impact of WNv on greater sage-grouse have been limited and are typically economically prohibitive. Fowl vaccines used on captive sage–grouse were largely ineffective (mortality rates were reduced from 100 to 80 percent in 5 birds) (Clark et al. 2006, p. 17). Development of a sage-grouse specific vaccine would require a market incentive and development of an effective delivery mechanism for large numbers of birds (currently, the delivery is via intramuscular injection) (Marra et al. 2004, p. 399). Vaccinations would only benefit the individuals receiving the vaccine, and not their offspring, so vaccination would have to occur on an annual basis (Kilpatrick et al. 2007). Mosquito production from human-created water sources could be minimized if water produced during coal-bed natural gas development were re-injected versus surface discharge (Doherty 2007, p. 81). If this is not possible, surface water sources should be designed to minimize habitat suitability for the vector. For existing water sources, effective larval control should be implemented via the introduction of mosquito-eating fish or application of biological or chemical larvicides (Doherty 2007, p. 85). Mosquito control programs for reducing the number of adult mosquitoes may reduce the risk of WNv, but only if such methods are consistently and appropriately implemented (Doherty 2007). The benefits of such control need to be considered in light of the potential detrimental or cascading ecological effects of widespread spraying (Marra et al. 2004, p. 401).

Substantial new information on WNv and impacts on the greater sage-grouse has emerged since we completed our finding in 2005. The virus is now distributed throughout the species range and affected sage-grouse populations experience high mortality rates with resultant reductions in local population numbers. There is limited information that suggests that sage-grouse may be able to survive an infection; however, because of the apparent low-level of immunity widespread resistance in unlikely. The most significant factors affecting the persistence of WNv within the range of sage-grouse are related to ambient temperatures and surface water abundance and development. The continued development of anthropogenic water sources throughout the range of the species will likely increase the prevalence of the virus in sage-grouse, as predicted by Walker (2008) (see discussion above). Areas with intensive energy development (particularly Management Zones I and II) may be at a particularly high risk for continued WNv mortalities due to the development of surface water features, and the continued loss and fragmentation of habitats (see discussion of energy development). Impacts from this disease may act synergistically with other stressors resulting in reduction of population size, distribution, or persistence.

Small populations, such as the Columbia Basin area in Washington State (Management Zone VI) or the subpopulations within the bi-state grouping along the California and Nevada border (Management Zone IV) may also be at high risk of extirpation simply due to their low population numbers and the additive mortality WNv causes. Larger populations may be better able to “absorb” losses due to WNv (Naugle 2008) simply due to their size. As other impacts to grouse and their habitats affect these areas, these “refugias” may also be at risk (e.g. north-central Montana, southwestern WY, south-central Oregon). Existing and developing models suggest that the occurrence of WNv is likely to increase throughout the range of the species into the future.

The most significant factors affecting the persistence of WNv within the range of sage-grouse are related to ambient temperatures and surface water abundance and development, and local population sizes, with small, isolated populations at higher risk.

Natural Enemies—Predation

Predation is the most commonly identified cause of direct mortality for sage-grouse (Schroeder et al. 1999, p. 9; Connelly et al. 2000b, p. 228). Despite this fact, adult sage-grouse typically experience relatively high annual survival rates, suggesting that predation has little impact on breeding populations (Connelly et al. 1994 cited in

Connelly 2000, p.229). Greater sage-grouse have evolved with predators, and the identity and type of predator varies with sex, life stage, and location.

Adult male greater sage-grouse are most susceptible to predation during the mating season presumably because they are very conspicuous while performing their mating display at leks. Because leks are attended daily by numerous birds, predators may be attracted to these areas during the breeding season (Braun in litt. 1995). Connelly et al. (2000b, p.228) found that among 40 radio-collared males, 83 percent of the mortality was due to predation and 42 percent of those mortalities occurred between March and June. Adult female greater sage-grouse are most susceptible to predators while on the nest or during brood-rearing when they are with young chicks (Schroeder and Baydack 2001, p. 25). Connelly et al. (2000b, p. 228) found that among 77 radio-collared adult hens, 52 percent of the mortality was due to predation and 52 percent of those mortalities occurred between March and August. Because sage-grouse are highly polygynous with only a few males breeding per year, sage-grouse populations are likely more sensitive to predation upon females. There is, however, no evidence predators disproportionately target females. In fact, females typically have a higher survival rates than males (Crawford et al. 2004). Known predators of both male and female adult greater sage-grouse include coyotes (*Canis latrans*), bobcats (*Lynx rufus*), weasels (*Mustela* spp.), golden eagles, red-tailed hawks (*Buteo jamaicensis*), Swainson's hawks (*B. swainsoni*), and ferruginous hawks (*B. regalis*) (Hartzler 1974, pp. 532-536; Schroeder et al. 1999, p. 9; Rowland and Wisdom 2002, p. 14; Schroeder and Baydack 2001, p. 25).

Juvenile grouse are known to be susceptible to predation from badgers (*Taxidea taxus*), red foxes, coyotes, weasels, American kestrels (*Falco sparverius*), merlins (*F. columbarius*), northern harriers (*Circus cyaneus*), and other hawks (Braun in litt. 1995; Schroeder et al. 1999, p. 10). Estimations of predation rates on juvenile age classes, however, have been frustrated by the difficulties involved with attaching transmitters to young birds. Gregg et al. (2003a, 2003b, p. 17), after surgically implanting radio transmitters, found that chick predation mortality ranged from 27 percent to 51 percent in 2002 and 10 percent to 43 percent in 2003 on three study sites in Oregon. Mortality due to predation during the first few weeks after hatching was estimated to be 82 percent (Gregg et al. 2007, p. 648). Survival of juveniles to their first breeding season was estimated to be low (10 percent) and it is reasonable, given the sources of adult mortality, to assume that the majority of juvenile mortality can also be attributed to predation (Crawford et al. 2004, p. 4).

Sage grouse nests are also subject to varying levels of predation. Predation can be total (all eggs destroyed) or partial (>1 egg destroyed). However, hens abandon nests in either case (Coates, 2007, p. 26). Gregg et al. (1994, p. 164) reported that over a three year period in Oregon 106 of 124 nests (84 percent) were preyed upon. Non-predated nests had greater grass and forb cover than predated nests. Patterson (1952, p.104) reported nest predation rates of 41 percent (89 of 216) in Wyoming. Holloran and Anderson (2003, p. 309) reported a predation rate of 12 percent (3 of 26) in Wyoming. Moynahan (2007, p. 1777) attributed 131 of 258 (54 percent) nest failures to predation in Montana. Important nest predators of sage-grouse are common ravens, black-billed magpies (*Pica hudsonia*), red fox, and badgers. Ground squirrels (*Spermophilus* spp.) have also been frequently identified as an important predator of sage grouse nests (Patterson 1952, p. 107). However, the majority of studies have used indirect evidence based on nest remains to infer predator identity. Holloran and Anderson (2003, p. 309), however, video recorded the fate of 26 grouse nests in Wyoming. An elk (*Cervus elaphus*), black-billed magpie, and badger were responsible for the three nest predations observed. Ground squirrels were recorded at nests but did not destroy eggs. Coates (2007, pp.26-30) similarly placed cameras on 55 sage-grouse nests in Nevada. Ravens (n=10; 59 percent), badgers (n=7; 41 percent), and a domestic cow (n=1; 6 percent) were responsible for the observed nest predation. Ground squirrels (n=23) and Great Basin gopher snakes (*Pituophis catenifer deserticola*) (n=2) were observed at nests but no predation occurred.

Losses of breeding hens and young chicks to predation potentially can influence overall greater sage-grouse population numbers, as these two groups contribute most significantly to population productivity. Losses of nesting adult hens and nests to predation appear to be related to the amount of herbaceous cover surrounding the nest (Gregg et al. 1994, p. 164; Braun in litt. 1995; Braun 1998; Coggins 1998, p. 30; Connelly et al. 2000b, p. 975; Schroeder and Baydack 2001, p. 25). Nesting success of greater sage-grouse is positively correlated with the presence of big sagebrush and relatively thick grass and forb cover and females actively select nest sites with these qualities (Schroeder and Baydack 2001, p. 25; Hagen et al. 2007, p. 46). DeLong et al. (1995, p. 90) and Gregg et al. (1994, p. 164) found a lower probability of nest predation at nest sites with tall grass and medium shrub cover in Oregon. Removal of this cover, by any method (grazing, fire, mechanical), can reduce nest success and adult hen survival. Similarly, habitat alteration that reduces cover for young chicks can increase the rate of predation on this age class (Schroeder and Baydack 2001, p. 27).

Connelly et al. (2000, p. 977) provide guidelines for management of characteristics of sagebrush rangeland needed for productive sage-grouse habitat. Such guidelines are based on the scientific literature. However, the literature is frequently conflicted about the relative importance of various vegetative characteristics on sage-grouse nesting success. Coates (2007, p. 159) postulated that discrepancies may be explained by predator composition and abundance. Increased forb biomass and understory obstruction was strongly correlated with badger predation. Badgers primarily prey upon ground squirrels that are associated with dense forbs and bunchgrasses. Conversely, decreased canopy cover was strongly correlated with raven predation. Unlike badgers, ravens are frequently favored in human altered landscapes where they are subsidized with alternate food sources (e.g. landfills) and provided additional perching and nesting structures (Coates 2008, p.159). These same landscapes are often associated with decreased canopy cover for sage-grouse nests.

Agricultural development, landscape fragmentation, and human populations have the potential to increase predation pressure on all life stages of greater sage-grouse as compared to historical conditions by forcing birds to nest in less suitable or marginal habitats, by increasing travel time through habitats where they are vulnerable to predation, and by increasing the diversity and density of predators (Ritchie et al. 1994, p. 125; Schroeder and Baydack 2001, p. 25; Connelly et al. 2004, p. 7-23; Summers et al. 2004, p. 523). Increasing populations of predators such as red fox and corvids, that historically were rare in the sagebrush landscape, but have increased in association with human-altered landscapes, are very effective nest predators (Sovada et al. 1995, p. 5) and have the potential to increase rates of predation on sage-grouse. In the Strawberry Valley of Utah (Management Zone II), Bambrough et al. (2000) noted that low survival of greater sage-grouse may have been due to an unusually high density of red foxes, which apparently were attracted to that area by anthropogenic activities. Connelly et al. (2004, p. 12-2) noted that ranches, farms, and housing developments have resulted in the introduction of nonnative predators including domestic dogs (*Canis domesticus*) and cats (*Felis domesticus*) into greater sage-grouse habitats. Where greater sage-grouse habitat has been altered in localized areas, the influx of predators can decrease annual recruitment into a population (Gregg et al. 1994, p. 164; Braun in litt. 1995; Braun 1998; DeLong et al. 1995, p. 91; Schroeder and Baydack 2001, p. 28).

Research conducted to determine nest success and greater sage-grouse survival has concluded that predation typically does not limit greater sage-grouse numbers although negative effects at local levels have been observed. (Connelly and Braun 1997, p. 7; Bambrough et al. 2000; Connelly et al. 2000a, p. 975; Connelly et al. 2000b, p. 229; Wambolt et al. 2002, p. 13). This conclusion is supported by evidence that predator removal does not have long-lasting effects on sage-grouse population size or stability over large regions (Cote and Sutherland 1997; Schroeder et al. 1999, p. 17; Wambolt et al. 2002, p. 14). For example, Slater (2003, p. 133) demonstrated that coyote control failed to have an effect on greater sage-grouse nesting success in southwestern Wyoming. Coyotes, however, may not be an important predator of sage-grouse. In a coyote prey base analysis, Johnson and Hansen (1979, p. 954) showed that sage-grouse and bird egg shells made up a very small percentage (0.4-2.4 percent) of analyzed scat samples. Additionally, the effects of coyote removal can have unintended consequences resulting in the release of mesopredators, many of which, like the red fox, may have greater negative impacts on sage-grouse (Mezquida et al. 2006, p. 752). Coates (2007, p. 37) found that ravens, unlike mammalian predators, depredated greater sage-grouse nests on a larger landscape and were associated with anthropogenic-altered areas. Removal of ravens caused only short-term reductions in raven populations (<1 year) as apparently transient birds from neighboring sites repopulated the removal area (Coates 2007, p. 151). Additionally, badger predation appeared to partially compensate for decreases in raven removal. No raven predation occurred within 20 km of the raven removal area whereas 6 of 7 (86 percent) of badger predations, which represented 41 percent of all predations, occurred within 15 km of the raven removal area. (Coates 2007, p 152). In their review of literature regarding predation, Connelly et al. (2004, p. 10-1) noted that only two of nine studies examining survival and nest success indicated that predation had limited a sage-grouse population by decreasing nest success, and both studies indicated low nest success due to predation was ultimately related to poor nesting habitat. Connelly et al. (2004, p. 10-2) further noted that the idea that predation is not a widespread factor depressing sage-grouse populations is supported by studies of nest success rates (which indicate nest predation is not a widespread problem), by the relatively high survival of adult birds, and by the lack of an effect on nesting success as a result of coyote control in Wyoming.

Sage-grouse have evolved with predators and have behavioral, morphological, and physiological characteristics that appear to help them avoid predators. Both female and male plumage is highly cryptic. When handled, birds often will drop large quantities of body and tail feathers as an escape mechanism. Birds are hesitant to flush and frequently remain crouched in cover despite being approached. Incubating females leave nests for short periods of time in a crepuscular pattern to minimize detection by visual predators (Coates 2008; p. 69). Sage-grouse, however, may be increasingly subject to levels of predation that would not normally occur in the historically contiguous unaltered sagebrush habitats.

In summary, greater sage-grouse are prey, and in a few instances predation appears to have been limiting to greater sage-grouse population stability. However, a review of the scientific literature indicates that in general, predation does not limit breeding populations of greater sage-grouse. Impacts of predation on the greater sage-grouse can increase where habitat quality has been compromised by anthropogenic activities (exurban development, road development, etc.). Studies of the effectiveness of predator control have failed to demonstrate an inverse relationship between the predator numbers and sage-grouse nesting success or populations numbers.

OTHER NATURAL AND MAN-MADE THREATS

Pesticides

According to the U.S. Environmental Protection Agency (USEPA) a "pesticide is any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest. Though often misunderstood to refer only to insecticides, the term pesticide also applies to herbicides, fungicides, and various other substances used to control unwanted organisms. Pests are living organisms that occur where they are not wanted or that cause damage to crops or humans or other animals" http://www.epa.gov/pesticides/about/index.htm#what_pesticide, October 7, 2008). Pesticides can potentially affect sage-grouse through impacts to habitat quality, abundance of prey items, and direct affects to the bird's health and survival.

Few studies have examined the effects of pesticides to sage-grouse, but at least one has documented direct mortality of greater sage-grouse as a result of ingestion of alfalfa sprayed with organophosphorus insecticides (Blus et al. 1989, Blus and Connelly 1998). In this case, a field of alfalfa was sprayed with dimethoate when approximately 200 sage-grouse were present; 63 of these sage-grouse were later found dead, presumably as a result of pesticide exposure (Blus et al. 1989, Blus and Connelly 1998). A comparison of applied levels of herbicides with toxicity studies of grouse, chickens, and other gamebirds (Carr 1968, as cited in Call and Maser 1985) concluded that herbicides applied at recommended rates should not result in sage-grouse poisonings.

Game birds that ingested sub-lethal levels of pesticides have been observed exhibiting abnormal behavior that may lead to a greater risk of predation (Dahlen and Haugen 1954, McEwen and Brown 1966, Blus et al. 1989). McEwen and Brown (1966) reported that wild sharp-tailed grouse poisoned by malathion and dieldrin exhibited depression, dullness, slowed reactions, irregular flight, and uncoordinated walking. Although no research has explicitly studied the indirect levels of mortality from sub-lethal doses of pesticides (e.g., predation of impaired birds), it has been assumed to be the reason for mortality among some study birds (McEwen and Brown 1966, Blus et al. 1989, Connelly and Blus 1991). Both Post (1951) and Blus et al (1989) located depredated sage-grouse carcasses in areas that had been treated with insecticides. Exposure to these insecticides may have predisposed sagegrouse to predation. Sage-grouse mortalities were also documented in a study where they were exposed to strychnine bait type used to control small mammals (Ward et al. 1942 as cited in Schroeder et al. 1999).

Much of the research related to pesticides that had either lethal or sub-lethal affects on greater sage-grouse was done on pesticides that have been banned or have their use further restricted for more than 20 years due to their toxic effects on the environment (e.g., dieldrin). We currently do not have any information to show that the banned pesticides through either illegal use or residues in the environment are presently having negative impacts to sage-grouse populations. For example, sage-grouse mortalities were documented in a study where they were exposed to strychnine bait used to control small mammals (Ward et al. 1942 as cited in Schroeder et al. 1999). According to the USEPA, in 1988, above-ground uses of strychnine were prohibited by a U.S. Court injunction and strychnine products with those uses remain temporarily cancelled. Currently Strychnine is currently registered with USEPA for use only below-ground as a bait application to control pocket gophers (Thomomys sp.) (USEPA 1996). Therefore, the current use of strychnine baits is unlikely to present a significant exposure risk to sage-grouse. We have no other information regarding mortalities or sublethal effects of strychnine or other banned pesticides on sage-grouse.

Although a reduction in insect population levels resulting from insecticide application can potentially affect nesting sage-grouse females and chicks (Willis et al. 1993, Schroeder et al. 1999), we have no information as to whether insecticides are impacting survivorship or productivity of the greater sage-grouse. Eng (1952) noted that after a pesticide was sprayed to reduce grasshoppers, songbird and corvid nestling deaths ranged from 50 to 100 percent depending on the chemical was used, and stated it appeared that nestling development was adversely affected due to the reduction in grasshoppers. Potts (1986 in Connelly and Blus 1991) determined that reduced food supply resulting from the use of pesticides ultimately resulted in high starvation rates of partridge chicks. In a similar study on partridges, Rands (1985) found that pesticide application adversely affected brood size and chick survival by reducing chick food supplies.

Three approved insecticides, carbarayl, diflubenzuron, and malathion, currently are available for application across the extant range of sage-grouse as part of implementation of the Rangeland Grasshopper and Mormon Cricket Suppression Control Program, under the direction of the Animal and Plant Health Inspection Service (APHIS) (APHIS 2004). Carbaryl is applied as bait, while diflubenzuron and malathion are sprayed. APHIS requires that application rates be in compliance with U.S. Environmental Protection Agency regulations, and APHIS has general guidelines for buffer zones around sensitive species habitats. These pesticides are applied for grasshopper and Mormon cricket control when requested by private landowners (APHIS 2004). Due to delays in developing nationwide protocols for application procedures, APHIS did not perform any grasshopper or Mormon cricket suppression activities in 2006, 2007, or 2008 (Gentle 2008).

In the Rangeland Grasshopper and Mormon Cricket Suppression Program Final Environmental Impact Statement—2002 (page 10), APHIS concluded that there "is little likelihood that the insecticide APHIS would use to suppress grasshoppers would be directly or indirectly toxic to sage grouse. Treatments would typically not reduce the number of grasshoppers below levels that are present in nonoutbreak years." APHIS (2002, page 69) discussed that although "malathion is also an organophosphorus insecticide and carbaryl is a carbamate insecticide, malathion and carbaryl are much less toxic to birds" than other insecticides associated with affects to sage-grouse or other wildlife. APHIS explains (page 6) "Because diflubenzuron is a chitin inhibitor that disrupts insects from forming their exoskeleton, organisms without a chitinous exoskeleton, such as mammals, fish, and plants are largely unaffected by diflubenzuron." The APHIS risk assessment (pages 122-184) for this EIS determined that the grasshopper treatments would not directly affect sage grouse. As to potential affects to prey abundance APHIS, noted that during "grasshopper outbreaks when grasshopper densities can be 60 or more per square meter (Norelius and Lockwood, 1999), grasshopper treatments that have a 90 to 95 percent mortality still leave a density of grasshoppers (3 to 6) that is generally greater than the average density found on rangeland, such as in Wyoming, in a normal year (Schell and Lockwood, 1997)."

Herbicide applications can kill sagebrush and forbs important as food sources for sage-grouse (Carr 1968 as cited in Call and Maser 1985). The greatest impact resulting from a reduction of either forbs or insect populations is for nesting females and chicks due to the loss of potential protein sources that are critical for successful egg production and chick nutrition (Schroeder et al. 1999; Johnson and Boyce 1991).

In summary, pesticides can result in direct mortality of individuals, and can also reduce the availability of food sources, which in turn could contribute to mortality of sage-grouse. Despite the potential effects of pesticides, we could find no information to indicate that the use of these chemicals, at current levels, negatively affects greater sage-grouse at the population level, although Schroeder et al.'s (1999, p.16) literature review found that the loss of insects can have significant impacts on nesting females and chicks. Those impacts were not detailed. Many of the pesticides that have been shown to have an effect on sage-grouse have been banned in the U.S. for more than 20 years. As previously noted, we currently do not have any information to show that the banned pesticides through either illegal use or residues in the environment are presently having negative impacts to sage-grouse populations.

Contaminants

Greater sage-grouse exposure to various types of environmental contaminants may potentially occur as a result of agricultural and rangeland management practices, mining, energy development and pipeline operations, nuclear energy production and research, and transportation of materials along highways and railroads.

A single greater sage-grouse was found covered with oil and dead in a wastewater pit associated with an oil field development in 2006; the site was in violation of legal requirements for screening the pit (Domenici 2008). To the extent that this source of mortality occurs it would be most likely in Management Zones I and II, as those zones are where most of the oil and gas development occurs in relation to occupied sage-grouse habitat. The extent to which such mortality to greater sage-grouse is occurring is extremely difficult to quantify due to difficulties in retrieving and identifying oiled birds, and lack of monitoring. We expect that the number of sage-grouse occurring in the immediate vicinity of such wastewater pits would be small due to the typically intense human activity in these areas, the lack of cover around the pits, and the fact that sage-grouse do not need free water. Most bird mortalities recorded in association with wastewater pits are water-dependant species (e.g. waterfowl), whereas dead grounddwelling birds (such as the greater sage-grouse) are rarely found at such sites (Domenici, 2008). However, if the wastewater pits are not appropriately screened, sage-grouse may have access to them and could ingest water and/or become oiled while pursing insects; if these birds then return to sagebrush cover and die their carcasses are unlikely to be found, as only the pits are surveyed. The effects of areal pollutants resulting from oil and gas development on greater sage-grouse are discussed in the energy development section above.

Numerous gas and oil pipelines occur within the occupied range of several populations of the species. Exposure to oil or gas from pipeline spills or leaks could cause mortalities or morbidity to greater sage-grouse. Similarly, given the extensive network of highways and railroad lines that occur throughout the range of the greater sage-grouse there is some potential for exposure to contaminants resulting from spills or leaks of hazardous materials being conveyed along these transportation corridors. We found no documented occurrences of impacts to greater sage-grouse from such spills, and we do not expect they are a significant source of mortality because these types of spills occur infrequently and involve only a small area that might be within the occupied range of the species.

Exposure of sage-grouse to radionuclides (radioactive atoms) has been documented at the U.S. Department of Energy's Idaho National Engineering Laboratory in eastern Idaho; although radionuclides were present in greater sage-grouse at this site, there were no apparent harmful effects to the population (Connelly and Markham 1983).

There are no nuclear power plants currently within the area of current distribution of the greater sage-grouse and there is only one that occurs in range formerly occupied by the species (Nuclear Energy Institute webpage www.nei.org 2004). Construction is scheduled to begin on a new nuclear power plant facility in 2009 in Elmore County, Idaho, near Boise (www.nei.org, October, 2008), in management zone IV. At this new facility and any other future new facilities developed for nuclear power, if all provisions regulating nuclear energy development are followed it is unlikely that there will be impacts to sage-grouse as a result of radionuclides or any other nuclear products.

Recreational Activities

Boyle and Samson (1985) determined that non-consumptive recreational activities can degrade wildlife resources, water, and the land by distributing refuse, disturbing and displacing wildlife, increasing animal mortality, and simplifying plant communities. Sage-grouse response to disturbance may be influenced by the type of activity, recreationist behavior, predictability of activity, frequency and magnitude, activity timing, and activity location (Knight and Cole 1995). Examples of recreational activities in sage-grouse habitats include hiking, camping, pets, and off-highway vehicle (OHV) use. As in 2005, we have not located any published literature concerning recreational effects on greater sage-grouse. Baydack and Hein (1987) reported displacement of male sharp-tailed grouse at leks from human presence resulting in loss of reproductive opportunity during the disturbance period. Female sharp-tailed grouse were observed at undisturbed leks while absent from disturbed leks during the same time period (Baydack and Hein 1987). Disturbance of incubating female sage-grouse could cause displacement from nests, increased predator risk, or loss of nests. Disruption of sage-grouse during vulnerable periods at leks, or during nesting or early brood rearing, however, could affect reproduction or survival (Baydack and Hein 1987). We were unable to find any published information specifically regarding effects to sage-grouse as a result of these factors. However, sage-grouse avoidance of activities associated with energy field development (e.g. Holloran 2005, Doherty et al. 2007), suggest these birds are likely disturbed by any persistent human presence. Additionally, Aldridge et al. (in press, pages 15-16) reported that the density of humans in 1950 was the best predictor of extirpation of greater sage-grouse. The authors also determined that sage-grouse have been extirpated in virtually all counties reaching a human population density of 25 people/km^2 by 1950. However, their analyses considered all impacts of human presence, and did not separate recreational activities from other associated activities and infrastructure. The presence of pets in proximity to sage-grouse can result in sage-grouse mortality or disturbance, and increases in garbage from human recreators can attract sage-grouse predators and help maintain their numbers at increased levels. Leu et al. (2008, page 1133) reported that slight increases in human densities in ecosystems with low biological productivity (such as sagebrush) may have a disproportionally negative impact on these ecosystems due to the potentially reduced resiliency to anthropogenic disturbance.

Indirect effects to sage-grouse from recreational activities include impacts to vegetation and soils, and facilitating the spread of invasive species. Payne et al. (1983) studied OHV impacts to rangelands in Montana, and found long-term (2 years) reductions in sagebrush shrub canopy cover as the result of repeated trips in the area. Increased sediment production and decreased soil infiltration rates were observed after disturbance by motorcycles and four-wheel drive trucks on two desert soils in southern Nevada (Eckert et al. 1979). However, we could find no information that quantified impacts to the sagebrush community or to sage-grouse populations.

We are unaware of scientific reports documenting direct mortality of greater sage-grouse through collision with off-road vehicles. Similarly, we did not locate any scientific information documenting instances where snow compaction as a result of snowmobile use precluded greater sage-grouse use, or affected their survival in wintering areas. Off-road vehicle or snowmobile use in winter areas may increase stress on birds and displace sage-grouse to less optimal habitats. However, there is no empirical evidence available documenting these effects on sage-grouse, nor could we find any scientific data supporting the possibility that stress from vehicles during winter is limiting greater sage-grouse populations.

Life History Traits Affecting Population Viability

Sage-grouse have comparatively low reproductive rates and high annual survival (Schroeder et al. 1999; Connelly et al. 2000a), resulting in slower potential or intrinsic population growth rates than is typical of other game birds. Therefore, recovery of populations after a decline from any reason may require years. Also, as a consequence of their site fidelity to breeding and brood-rearing habitats (Lyon and Anderson), measurable population effects may lag behind negative habitat impacts (Wiens and Rotenberry 1985). While these natural history characteristics would not limit sage-grouse populations across large geographic scales under historical conditions of extensive habitat, they may contribute to local population declines when humans alter habitats or mortality rates.

Sage-grouse have one of the most polygamous mating systems observed among birds (Deibert 1995). Asymmetrical mate selection (where only a few of the available members of one sex are selected as mates) should result in reduced effective population sizes (Deibert 1995), meaning the actual amount of genetic material contributed to the next generation is smaller than predicted by the number of individuals present in the population. With only 10 to 15 percent of sage-grouse males breeding each year (Aldridge and Brigham 2003), the genetic diversity of sage-grouse would be predicted to be low. However, in a recent survey of 16 greater sage-grouse populations, only the Columbia Basin population in Washington showed low genetic diversity, likely as a result of long-term population declines, habitat fragmentation, and population isolation (Benedict et al. 2003; Oyler-McCance et al. 2005, p. 1307). The level of genetic diversity in the remaining range of sage-grouse has generated a great deal of interest in the field of behavioral ecology, specifically sexual selection (Boyce 1990; Deibert 1995). There is some evidence of off-lek copulations by subordinate males, as well as multiple paternity within one clutch (Connelly et al. 2004). Dispersal may also contribute to genetic diversity, but little is known about dispersal in sage-grouse (Connelly et al. 2004).

However, the lek breeding system suggests that population sizes in sage-grouse must be greater than in non-lekking bird species to maintain long-term genetic diversity.

Aldridge and Brigham (2003) estimated that up to 5,000 individual sage-grouse may be necessary to maintain an effective population size of 500 birds. Their estimate was based on individual male breeding success, variation in reproductive success of males that do breed, and the death rate of juvenile birds. We were unable to find any other published estimates of minimal population sizes necessary to maintain genetic diversity and long-term population sustainability in sage-grouse.

Drought

Drought is a common occurrence throughout the range of the greater sage-grouse (Braun 1998) and is considered a universal ecological driver across the Great Plains (Knopf 1996, p.147). Infrequent, severe drought may cause local extinctions of annual forbs and grasses that have invaded stands of perennial species, and recolonization of these areas by native species may be slow (Tilman and El Haddi 1992). Drought reduces vegetation cover (Milton et al. 1994; Connelly et al. 2004), potentially resulting in increased soil erosion and subsequent reduced soil depths, decreased water infiltration, and reduced water storage capacity. Drought can also exacerbate other natural events, such as defoliation of sagebrush by insects. For example, approximately 2,544 km^2 (982 mi^2) of sagebrush shrublands died in Utah in 2003 as a result of drought and infestations with the *Aroga* (webworm) moth (Connelly et al. 2004). Sage-grouse are affected by drought through the loss of vegetative habitat components, reduced insect production (Connelly and Braun 1997), and potentially exacerbation of WNv infections as described in Natural Enemies C above. These habitat component losses can result in declining sage-grouse populations due to increased nest predation and early brood mortality associated with decreased nest cover and food availability (Braun 1998; Schroeder et al. 1999).

Sage-grouse populations declined during the 1930s period of drought (Patterson 1952; Willis et al. 1993; Braun 1998). Drought conditions in the late 1980s and early 1990s also coincided with a period when sage-grouse populations were at historically low levels (Connelly and Braun 1997). From 1985 through 1995, the entire range of sage-grouse experienced severe drought (as defined by the Palmer Drought Severity Index) with the exceptions of north-central Colorado (Management Zone II) and southern Nevada (Management Zone III). During this time period drought was particularly prevalent in southwestern Wyoming, Idaho, central Washington and Oregon, and northwest Nevada (http://www.drought.unl.edu, October 17, 2008). Abnormally dry to severe drought conditions still persist in Nevada and western Utah (management zones III and IV), Idaho (management zone IV), northern California and central Oregon (management zone V), and southwest Wyoming (Management zone II) (http://www.drought.unl.edu/dm/monitor.html).

Aldridge et al. (2008) found that the number of severe droughts from 1950 to 2003 had a weak negative effect on patterns of sage-grouse persistence (p. 992).

However, they cautioned that drought may have a greater influence on futhre sage-grouse populations as temperatures rise over the next 50 years, and synergistic effects of other threats affect habitat quality (Aldridge et al. 12008, p. 992).

In summary, drought has been a consistent and natural part of the sagebrush-steppe ecosystem and there is no information to suggest that drought was a cause of persistent population declines of greater sage-grouse under historic conditions. However, drought impacts on the greater sage-grouse may be exacerbated when combined with other habitat impacts that reduce cover and food (Braun 1998).

Climate Change

Climate change at the global scale: The Intergovernmental Panel on Climate Change (IPCC) is a scientific body set up by the World Meteorological Organization and the United Nations Environment Program in 1988. It was established to provide policymakers needed an objective source of information about the causes of climate change, its potential environmental and socio-economic consequences, and the adaptation and mitigation options to respond to it. In 2007, the IPCC published its Fourth Assessment Report, which is considered the most comprehensive compendium of information on actual and projected global climate change currently available.

Although the extent of warming likely to occur is not known with certainty at this time, the IPCC (2007a, p. 5) has concluded that warming of the climate is unequivocal and that continued greenhouse gas emissions at or above current rates will cause further warming (IPCC 2007a, p. 13). The IPCC also projects that there will very likely be an increase in the frequency of hot extremes, heat waves, and heavy precipitation (IPCC 2007a, p. 15).

Climate change may alter global ecosystems. Species' geographic ranges are to a large extent limited by climatic conditions such as temperature and rainfall patterns which interact dynamically with other ecosystem factors such as local physiography (e.g., physical substrate, topography) that can in turn affect competition, predation and other species interactions. All of these together shape habitat and species distributions. Climate changes may lead to a shift of climatically suitable ranges to higher altitudes and/or poleward (McCarty 2001, p. 324). Climate changes may alter species' phenologies such as time of nest initiation (Crick 2004, p. 50) and timing of migration (Butler 2004, p. 487).

Potential effects on sagebrush habitats: Current climate change projections reflect the potential for both positive and negative affects on sage-grouse through changes in sagebrush habitat. These changes in sagebrush habitats are expected to occur primarily through the mechanisms of increased temperature and alterations in the amount precipitation, both within seasons and annually.

Climate changes may facilitate, curtail, or reverse exotic species invasions that are under way in the sagebrush biome (Bradley in press, pp. 1-45). Cheatgrass is an invasive species that has colonized extensive portions of sagebrush habitats primarily in the western and southern portion of greater sage-grouse range (Management Zones III, IV, and V). Cheatgrass and the changes in fire-regime associated with it, is currently a significant threat to the greater sage-grouse. It reduces habitat quality directly by outcompeting native vegetation, and indirectly by increasing fire frequency which removes sagebrush and expands the spread of cheatgrass (see cheatgrass discussion under Invasives above). Bradley (in press, pp 9-15) developed a bioclimatic model for cheatgrass based on its invaded distribution that projected the potential for cheatgrass habitat by 2100. She found that the best predictors of cheatgrass occurrence are summer, annual, and spring precipitation, followed by winter temperature. She then used projections of 10 atmosphere-ocean general circulation models for the year 2100. Depending primarily on future precipitation conditions, Bradley found that suitable land area for cheatgrass could increase by as much as 45 percent, or decrease by as much as 70 percent by 2100 (Bradley in press, pp 17). Bradley noted that most of the climate change scenarios she explored resulted in a decrease in climatic habitat for cheatgrass (Bradely in press, pp 21). Warming in the range of greater sage grouse is expected to be greatest in the winter (IPCC 2007b, Fig. 11.12, p. 890), annual mean precipitation is likely to increase, and the length of snow season and snow depth is likely to decrease (IPCC 2007b, p. 887). In general, increased annual precipitation and winter temperature would result in a decrease in suitable land area for cheatgrass by 2100, according to Bradley,s model (in press, pp 16-20; 36).

Bradley (in press, pp 21) stated that the bioclimatic model she used is an initial step in assessing the potential geographic extent of cheatgrass, because climate conditions only affect invasion on the broadest regional scale. Other factors relating to land use, soils, competition or topography may affect suitability of a given location (Bradley in press, pp 22).

In a study that modeled potential impacts to big sagebrush (*Artemesia tridentata*) due to climate change, Shafer et al. (2001, pp. 200-215) used response surfaces to describe the relationship between bioclimatic variables and the distribution of tree and shrub taxa in western North America. The response surfaces illustrate the probability of the occurrence of taxon at particular points in climate space, which is defined by three bioclimatic variables: mean temperature of the coldest month, growing degree days, and a moisture index. Species distributions were simulated under present climate using observed data (1951-80, 30-year mean) and under future climate (2090-99, 10-year mean) using scenarios generated by three general circulation models – HADCM2, CGCM1, and CSIRO. Each scenario produced similar results, simulating future bioclimatic conditions that would reduce the size of the overall range of sagebrush and change where sagebrush may occur. These simulated changes were the result of increases in the mean temperature of the coldest month which the authors speculated may interact with soil moisture levels to produce the simulated impact. Each model predicted that climate suitability for big sagebrush would shift north into Canada. Areas in the current range would become less suitable climatically, and would potentially cause significant contraction. The authors also point out that increases in fire frequency under the simulated climate projections would leave big sagebrush more vulnerable to fire impacts.

Shafer et al. note the limitations of their projections citing similar factors. Shafer et al. (2001, pp 213) explicitly state that their approach should not be used to predict the future range of a species, and that the underlying assumptions of the models they used are "unsatisfying" because they presume a direct causal relationship between the distribution of a species and particular environmental variables. Shafer et al. (in press, pp 207, 213) identify cautions similar to Bradley (in press, pp 21) regarding their models. A variety of factors are not included in climate space models, including: the effect of elevated CO_2 on the species' water-use efficiency, what really is the physiological effect of exceeding the assumed (modeled) bioclimatic limit on the species, the life stage at which the limit effects the species (seedling versus adult), the life span of the species, and the movement of other organisms into the species range (Shafer et al., 2001, pp 207). These would likely help determine how climate change would affect species distributions. Shafer et al. (2001, pp 213) concludes that while more empirical studies are needed on what determines a species and multi-species distributions, those data are often lacking; in their absence climatic space models can play an important role in characterizing the types of changes that may occur so that the potential impacts on natural systems can be assessed.

The World Wildlife Fund developed a bioclimatic envelope model for big sagebrush and silver sagebrush in the states of Montana, Wyoming, and North and South Dakotas (World Wildlife Fund 2008, pp. 1-28). The WWF study suggests that large displacement and reduction of sagebrush habitats will occur under climate change as early as 2030 for both species of sagebrush examined. The methodology used by WWF to develop their model appears in some ways similar to that of Shafer et al. (2001); however, it lacked an explanation of model assumptions and methodology, and a discussion of results; therefore its usefulness at this time is limited. Other models projecting the affect of climate change on sagebrush habitat, and discussed more below, identify uncertainty associated with projecting climatic habitat conditions into the future given the unknown influence of other factors that such models do not incorporate (e.g., local physiographic conditions, life stage of the plant, generation time of the plant and its reaction to changing CO_2 levels).

Uncertainty associated with climate change science: The Service is currently developing interim guidance regarding relevant aspects of Endangered Species Act implementation involving climate change, with a focus on how to evaluate and include the best available scientific information in our decision-making. We will re-evaluate and refine our guidance as climate change science relevant to the scale and nature of our responsibilities evolves. At this time, we rely on guidance from IPCC and the U. S. Geological Survey in applying climate change models at the continental scale. We also rely on empirical evidence of direct effects on a species, such as increased stream temperatures (see Rio Grande cutthroat trout, 73 FR 27900, May 14, 2008), or loss of sea ice (see polar bear, 73 FR 28212, May 15, 2008), are threat factors that can be analyzed, and may relate to climate change. However, we have no such data relating to greater sage-grouse. Application of continental scale climate change models to regional landscapes, and models projecting habitat potential based on climatic factors, while informative, contain a high level of uncertainty due to regional weather patterns, local physiographic conditions, life stages of individual species, generation time of species, and species reactions to changing CO2 levels. The models summarized above are limited by these factors; therefore their usefulness is assessing the threat of climate change on greater sage-grouse is also limited.

Information on the potential threat of climate change on greater sage-grouse is limited; no evidence of direct effects to the species exist at this time. Changes in phenology (timing of breeding or migration) due to climate change have been documented in other avian species (Butler 2003, Crick 2004), but this has not been studied in greater sage-grouse. Butler (2003, pp 487) found evidence that local migrants (species within continent) are arriving significantly earlier on breeding grounds than long-range migrants, due to their apparent ability to react to local weather patterns. Although speculative, this suggests that greater sage-grouse, as a local migrant, may be able to adapt the timing of their migration to potential changes in the availability of habitat and food on nesting grounds due changes in climate.

Climate change may also cause indirect effects that occur over time; these may positively affect greater sage-grouse (e.g., curtail or reverse invasion of habitat by cheatgrass) or negatively affect sage-grouse (e.g., significant loss of sagebrush habitat). Conclusions regarding direct and indirect effects from climate change are uncertain at this time.

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